NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

EARTH RESOURCES SURVEY PROGRAM

TECHNICAL LETTER NASA-3

INTERIM REPORT OF ULTRAVIOLET ABSORPTION AND STIMULATED LUMINESCENCE INVESTIGATIONS BEING UNDERTAKEN IN COOPERATION WITH THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PART I — ULTRAVIOLET VIDEO IMAGING SYSTEM

By William R. Hemphill and Stephen J. Gawarecki

PART II — SPECTRAL DISTRIBUTION OF ULTRAVIOLET STIMULATED LUMINESCENCE

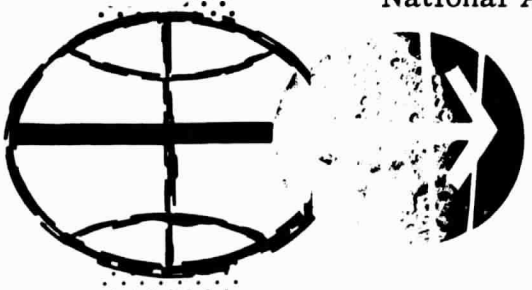
By William A. Fischer and David L. Daniels

PART III — MEASUREMENT OF ULTRAVIOLET REFLECTANCE

By William A. Fischer and Reinhold Ferharz

November 1964

Prepared by the Geological Survey for the
National Aeronautics and Space Administration (NASA)



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey
Washington, D.C.

Technical Letter
NASA-3
November 1, 1964

Memorandum

To: Peter C. Badgley, Chief, Advanced Missions, Manned Space Science Program, NASA Headquarters, Washington, D.C. 20546

From: William A. Fischer, Chief, Remote Sensing Project, Branch of Theoretical Geophysics, Washington, D.C. 20242

Subject: Status and preliminary results of studies of the ultraviolet spectrum and its interactions with natural objects

Submitted herewith one (1) copy of:

TECHNICAL LETTER: NASA-3

INTERIM REPORT OF ULTRAVIOLET ABSORPTION AND STIMULATED LUMINESCENCE INVESTIGATIONS BEING UNDERTAKEN IN COOPERATION WITH THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Part I - Ultraviolet video imaging system
by
William R. Hemphill and Stephen J. Gawarecki

Part II - Spectral distribution of ultraviolet stimulated luminescence
by
William A. Fischer and David L. Daniels

Part III - Measurement of ultraviolet reflectance
by
William A. Fischer and Reinhold Gerharz

compiled by
William R. Hemphill and T. M. Sousa

This report includes measurements, observations, and some preliminary interpretations made in connection with the investigations of the ultraviolet spectrum on or before November 1, 1964. The report is intended as an interim report only and all interpretations, methods, and plans herein presented are subject to change as additional data are accumulated.

Copies distributed as follows:

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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INTERIM REPORT OF ULTRAVIOLET ABSORPTION AND STIMULATED LUMINESCENCE INVESTIGATIONS BEING UNDERTAKEN IN COOPERATION WITH THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTRODUCTION

Studies involving the interactions of parts of the ultraviolet spectrum with natural objects are being conducted by the U.S. Geological Survey ~~in cooperation with~~ and the Westinghouse Electric Corporation. These investigations are funded cooperatively by the Geological Survey and the National Aeronautics and Space Agency (NASA).

Principally these investigations are aimed at an appraisal of the value of the ultraviolet spectrum for mapping the surface chemical and/or physical characteristics of parts of the earth and the other planetary bodies. These investigations include development and appraisal of various types of instrument systems (both passive and active) which respond to or permit measurement of ultraviolet reflection or ultraviolet-stimulated luminescence.

At the present time two supporting studies are underway, 1) a three-phase appraisal of an ultraviolet video imaging system developed by the Westinghouse Electric Corporation, and 2) a program of measurement of the spectral distribution of ultraviolet stimulated luminescence. This latter investigation is primarily designed to provide data on which to base filter selection for use in the first investigation. A third study involving measurement of ultraviolet reflectance of various natural objects is now inactive, sufficient data having been gathered to satisfy the initial need for such data and to evaluate the usefulness of the equipment.

These three investigations are discussed separately in the succeeding parts of this report.

PART I

PART I - ULTRAVIOLET VIDEO IMAGING SYSTEM

by

William R. Hemphill and Stephen J. Gawarecki

General statement

The ultraviolet video imaging system, developed by Westinghouse Electric Corporation, was initially designed as a ranging and imaging device for use in low flying aircraft. The objective of this study is to appraise the suitability of this system for remote detection of luminescent minerals and rocks as well as for discriminating between non-luminescing rocks on the basis of absorption of electromagnetic energy of from 3300 to 4000 Å wavelength.

The study is divided into three phases. Phase I involves indoor laboratory tests using the equipment to image hand specimens of various luminescing and non-luminescing minerals. Phase II is similar to Phase I except that the tests will be conducted outdoors, bulk samples will be used, and meteorological conditions will be recorded for correlation with the test results. In Phase III, the equipment will be mounted in a van or a truck and tests will be performed at localities where luminescing minerals exist.

Phase I tests were completed October 27, 1964, and the results of these tests are outlined in this report.

Instrumentation

Basic operational components of the ultraviolet imaging system include an ultraviolet transmitter employing a flying spot scanner and a photomultiplier-type receiver so designed that its field of view is limited to an area slightly larger than the transmitter spot (fig. I-1); the scan of the transmitter spot and the receiver field is synchronized. The receiver output is connected to both an A-scope[1/] and a video monitor for simultaneous observation and measurement of intensity of luminescence and/or reflectance (figs. I-2, I-3, I-4, and I-5).

1/ An oscilloscope where signals appear as vertical excursions of the horizontal line, or trace.

Transmitter

The transmitter is a conventional cathode ray tube employing a P-16 phosphor and a raster scan pattern. Except for such details as raster shape, sweep speed, linearity, frame rate, and color, the tube face resembles a four inch television receiver.

Electron bombardment stimulates the P-16 phosphor to emit ultraviolet radiation at a peak emission of 3700 $\pm$ 400 Å (Appendix I-A). This radiation is transmitted via the optics (fig. I-1) and illuminates an area in the subject field which is equivalent to the projected size of the cathode ray tube spot. The scan causes all elements in the subject field to be illuminated in sequence. The decay time of the phosphor is of sufficiently short duration so that the resolution of the system is not degraded.

Receiver

The receiver consists of a CBS S-13 image dissector tube (spectral response of the S-13 is shown in Appendix I-A); this tube is not only as sensitive as a photomultiplier but it also has the advantage of providing an inertialess, scannable aperture. In this device an image is focused on the photocathode which converts it without integration into an electron impulse. This impulse is then focused on an electrode which is opaque except for a small hole or fixed aperture. Electrical deflection is provided in order to sweep the electron impulses across the aperture. Following the aperture is an electron multiplier which amplifies only those electrons passing through the aperture.

The receiver scanning aperture is slightly larger than the transmitter spot; in this way, the receiver reacts only to the peak power being developed by the transmitter. Integrated, the transmitter-receiver covers a subject field 25 degrees wide and 14 degrees high.

Procedure and preliminary evaluation of the results

In order to evaluate some of the critical limitations of the imaging system and to judge more effectively some of the parameters affecting the remote sensing of some luminescent minerals, the following experiments were performed. Throughout the study the input power was 0.5 ma at 20,000V or 10 watts.

Uniformity of image brightness

Preliminary inspection suggested that the imaging sensitivity of the UV imaging system was not uniform throughout the field of view; it was also suspected that the brightest images were in the center and that a vignetting effect prevailed along the margins. In order to check this possibility, five eight-inch square luminescent panels were arranged on a black cloth background 15 feet from the transmitter-receiver. Neither the transmitter nor the receiver were filtered. Initial results showed that the right two-thirds of the screen was the most evenly illuminated, but that the brightest image was located in the center (fig. I-6). It is not certain at this time whether this unevenness of image brightness is attributable to the transmitter, the receiver, or both.

Further experimentation with the luminescent panels showed that the depth of focus of the transmitter-receiver at a range of 15 feet is about five feet.

Discrimination

The ability of the ultraviolet video system to image specimens of luminescent minerals from distances up to 25 feet and to discriminate between two closely spaced specimens is surprisingly good. Figures I-7 and I-8 show the video monitor images and the A-scope peaks of scapolite on the left and hackmanite on the right. The two specimens are two to three inches in width, one inch apart, and 15 feet from the transmitter-receiver. Hackmanite is weakly luminescent compared to scapolite, thus, its higher peak on the A-scope is probably due to its slightly larger size.

Figures I-9 and I-10 show video monitor images of the same specimens one inch apart but 20 and 25 feet, respectively, from the transmitter-receiver. Although each specimen can be distinguished on the video monitor at these distances, definitive peaks on the A-scope were not observed beyond 15 feet. Figure I-11 shows the video monitor images of the specimens when placed one-half inch apart 25 feet from the transmitter-receiver.

During this series the transmitter was fitted with a Corning 7-56 filter (Appendix I-B) which essentially removed all visible light from the source. Unfortunately, however, the receiver could not be filtered because of power problems which restricted the transmitter operation to 40 per cent peak power; filtering the receiver would have required an increase in gain and caused imagery to be obscured by noise at distances of 20 and 25 feet. Thus, because the receiver could not be filtered, the imagery in figures I-7--I-11 shows reflected ultraviolet light as well as ~~fluorescence~~ luminescence.

To evaluate the ability of the sytem to detect small luminescing objects, a 4 by 18 inch piece of luminescent bunting was masked in strips three inches high and ranging in width from two inches on the left progressively smaller to one thirty-second inch on the right; thus, the target consists of seven ~~fluor~~ luminescent strips one inch apart and of varying widths. Figure I-12 shows the video monitor image of the target when placed 15 feet from the transmitter-receiver. The transmitter was filtered with a Corning 57-60, the receiver with a Corning 3-72 (Appendix I-C). Six strips as small as one-~~eight~~ sixteenth inch wide can be seen clearly, although their images are disproportionately broad. The seventh strip, one thirty-second inch wide, can also be seen, though more faintly than the others.

Throughout the testing program it was noted that strongly imaged specimens tend to obscure weaker ones to their right; this distortion is due to the sequential top to bottom, left to right scanning mechanism of the receiver. Though not serious, this "bleed through" was overcome in the laboratory by placing weakly luminescing minerals to the left of stronger ones. "Bleed through" is not expected to be a significant problem in the outdoor tests in Phases II and III.

Aspect angle

Other experimentation with luminescent panels shows that brightness of luminescence imaged by the receiver is independent of orientation of the subject. Figure I-13 shows the panel strongly imaged from a "face-on" orientation 15 feet from the transmitter-receiver. The transmitter is filtered with a Corning 7-60 which removes essentially all visible light; the receiver is unfiltered. Figure I-14 is the same except that the panel has been deliberately tilted; weak image of the tilted panel indicates that ultraviolet reflection is the cause for the strong image in figure I-13. In order to remove the effect of reflected ultraviolet light, the receiver was filtered with a Corning 3-72; although figure I-15 shows a face-on orientation of the panel, an equally strong image was made when the panel was turned indicating a near lambertian distribution of emitted energy.

Sensitivity compared with the naked eye

Preliminary study strongly suggests that the ultraviolet imaging system is more sensitive than the human eye. Specimens of fluorite and calcite were arranged 15 feet from the transmitter-receiver.with The transmitter was filtered with a Corning 7-54 (Appendix I-B); the receiver with a Corning 3-72. The power was deliberately reduced in order to determine the threshold of image visibility, both with the video system and with the naked eye viewing through a Corning 3-72 filter.

Quantitative comparison of sensitivity is inconclusive mainly because of the relative insensitivity of the milliammeter below .05 ma. However, relative threshold power ratings (05 ma and .25 ma) suggest that the imaging system may be more than 5X as sensitive as the human eye.

Environment

Although exhaustive environmental tests are beyond the scope of this investigation, some cursory studies of the effects of moisture and temperature were included in the Phase I program. The results are preliminary and not meant to be conclusive. They are included here as a matter of record.

Moisture--Five mineral specimens were arranged in two rows about 15 feet from the transmitter-receiver (Appendix I-D). Two specimens of calcite were placed in the top row; one specimen each of scapolite, fluorite, and calcite were arranged left to right in the bottom row. The transmitter was filtered by a Corning 57-54; the receiver by a Corning 3-73 (Appendix I-C). Figure I-16 shows the images of the dry specimens as imaged on the video monitor. Figure I-17 shows images of the specimens immediately after they have been immersed in water.

The two sets of images are essentially the same; any slight difference which may be detected is attributed to a cyclical variation in power which was noted throughout the Phase I program.

Temperature--Two pieces of calcite (from Moorefield, West Virginia) were broken from the same specimen and were oriented with common surfaces facing the transmitter-receiver 15 feet away. Both specimens were about three inches in diameter. Throughout this series of experiments, the transmitter was filtered with a Corning 57-54, the receiver with a Corning 3-73.

Figures I-18 and I-19 show both specimens at ambient temperature of 15.5°C.. The specimen on the left shows as a brighter video monitor image and higher A-scope peak; this is probably due to the fact that this specimen is slightly larger than the specimen at the right.

Figures I-20 and I-21 show the video monitor images and the A-scope peaks when the calcite specimen on the right was heated to 80°C; the temperature of the control specimen on the left remained at 22°C. Temperature of both specimens was measured with a contact pyrometer immediately before and after imaging. Cyclical variation in power is believed to cause the higher A-scope peaks shown in figure I-21 (in contrast to those in figure I-19). The difference between the A-scope peaks of the control specimen and the temperature-varied specimen is essentially the same, however, suggesting that heating the specimen to 80°C had no detectable effect on its luminescing properties.

Figures I-22 and I-23 show the video monitor and A-scope after the heated specimen had been allowed to cool to 40°C. Again, the difference between the A-scope peaks of the control specimer and the temperature-varied specimen, as shown in figures I-19, I-21 and I-23 are essentially the same.

Figures I-24 and I-25 show the video monitor and the A-scope after the temperature-varied specimen has been cooled to about -30°C; the specimen on the left remains at 22°C. Here both the video monitor image and the A-scope peak of the temperature-varied specimen has increased to where it is nearly equal in intensity to that of the control specimen. This increase is believed to reflect an increase in luminescence in the cooled specimen which could be detected by the receiver 15 feet away. Similar phenomena have been noted by other investigators.

Filters

In order to evaluate the suitability of the imaging system in determining the luminescence signature of specific minerals, a series of filters was introduced in the receiver to limit the band pass to discrete parts of the visible spectrum beyond 4000 Å (Appendix I-C). Two groups of minerals were studied in this series of experiments. The first group included hand samples of minerals most of which were luminescing; the second group included specimens chosen from bulk samples of minerals selected on the basis of their property to luminesce under "long" wavelength ultraviolet light. These bulk samples are to be used in the outdoor tests in Phase II.

Preliminary study of both groups of minerals was undertaken with the aid of a monochrochromator and various UV sources in order to obtain the spectral luminescence curves for each sample, thereby guiding the choice of filters to be used in the UV video imaging system (see Part II of this report).

UV Imaging System - Group I Minerals--The nine samples used in this study were arranged as shown in Appendix I-E, 15 feet from the transmitter-receiver. Throughout the study the transmitter was filtered with a Corning 5754 filter.

Figure I-26 and I-27 show the video monitor images and the A-scope peaks of the nine minerals. Because the receiver was not filtered, both the video monitor and the A-scope show reflected UV as well as any luminescence that some of the minerals may be exhibiting.

Figures I-28 and I-29 show the video monitor images and the A-scope peaks after a Corning 3-73 filter has been installed in the receiver. This filter restricts the band pass to wavelengths longer than 4000 Å. The minerals in the top line are barely visible but scapolite and fluorite show strongly in the bottom line. Calcite is not visible but the quartz is visible on the left; although this specimen is predominantly scheelite, it is oriented so that a quartz surface faces the transmitter-receiver. The visibility of the quartz is believed to be due to reflection of extraneous visible light from its crystal surfaces. That this image represents luminescence of the scheelite transmitted through the quartz is discounted inasmuch as scheelite luminesces under shortwave UV only.

Figure I-30 shows the video monitor image after a Corning 3-72 filter has been installed on the receiver. This filter restricts the band pass to wavelengths longer than 4300 Å. The top line is not visible. Scapolite is strongly imaged on the bottom line; fluorite somewhat more weakly. Quartz reflection of visible light is seen on the left.

Figures I-31 and I-32 show the video monitor images and the A-scope peaks after a Kodak ~~K-4~~ filter has been installed in the receiver; this filter restricts the band pass to wavelengths longer than 4500 Å. Scapolite shows clearly, fluorite weakly. Presence of the quartz reflection is suggested by the weak pip on the A-scope to the left of the scapolite. Samples in the top row are not visible.

Figures I-33 and I-34 show the video monitor images and the A-scope peaks after a Kodak 8A (K-2) filter has been installed in the receiver; the Kodak 8A (K-2) restricts the band pass to wavelengths longer than 4700 Å. Scapolite continues to show strongly, fluorite weakly. Evidence of the quartz reflection can again be seen on both the A-scope and the video monitor. That it was not seen in figure I-31, where a Kodak ~~K-4~~ filter was used, is attributed to a cyclical variation in power which was noted through the Phase I program.

Figures I-35 and I-36 show the video monitor images and the A-scope peaks after a ~~Corning~~ Kodak 15g filter has been installed; this filter restricts the band pass to wavelengths longer than 5100 Å. Scapolite continues to show strongly but the fluorite is no longer visible. Reflection from the quartz face appears weakly on the video monitor to the left of the scapolite

Figures I-37 and I-38 show the video monitor and the A-scope peak after a ~~Corning~~ Kodak 16 filter has been installed; this filter restricts the band pass to wavelengths longer than 5200 Å. Scapolite is more prominent. The faint signal to the right of the scapolite on both the video monitor and the A-scope is apparently fluorite; that it was not seen in figures I-35 and I-36 is attributed to the cyclical variation in power mentioned earlier.

Filters beyond 5500 Å were not used in the program because of the band pass limits of the CBS S-13 image dissector tube (see Appendix I-A).

UV imaging system - Group II minerals--The six samples of fluorescing minerals, used in this study, were arranged as shown in Appendix I-F, 15 feet from the transmitter-receiver. A two-inch square window, cut out of cardboard, was placed in front of each mineral; in this way, each mineral exhibited an identical area to the transmitter-receiver. A magnesium oxide block was also included in order that relative amounts of reflected light could be noted as various filters were used. Throughout this series, the transmitter was filtered with a Corning 5754.

Figures I-39 and I-40 show the video monitor images and the A-scope peaks of the six mineral samples and the magnesium oxide standard. Because the receiver was not filtered, both the video monitor and the A-scope show reflected UV as well as any luminescence that some of the specimens may be exhibiting. An experimental calibration system, involving neutral density filters, was used to provide a method of contrasting gain levels required for detection of the specimens as various filters were introduced. The power level used in figure I-40 was arbitrarily selected as a reference standard for the following series.

Figures I-41 and I-42 show the video monitor images and the A-scope peaks after a Corning 3-73 filter was installed. Gain is about 37X that used in figure I-40. Fluorite and calcite, in the top line, and phosphate and colemanite, in the bottom line, are strongly visible. The specimen containing calcite veins is weakly visible on the left. Presence of willemite is suggested in the A-scope trace to the left of the fluorite peak; its appearance on the video monitor was intermittent due to the power variations mentioned earlier. Image of the magnesium oxide block is due to its high reflectivity; this compound does not luminesce under long wave ultraviolet lihgt. Its visibility in figures I-41 and I-42 (and in figures I-43 and I-44) may be due to leakage either of visible light through the transmitter filter or to ultraviolet light through the receiver filter.

Figures I-43 and I-44 show the video monitor images and the A-scope peaks after a Corning 3-72 filter has been installed. Phosphate and colemanite are strongly imaged but the calcite, fluorite, and the magnesium oxide block appear more weakly than in figures I-41 and I-42. Willemite is not visible. Gain is about 37X that used in figure I-40.

Figures I-45 and I-46 show the video monitor images and the A-scope peaks after a Kodak ~~K-4~~ filter has been installed in the receiver. Both phosphate and colemanite continue to show strongly but the brightness of fluorite and both calcites is diminished. The magnesium oxide block and the willemite are not visible. Gain is about 90X that used as a reference in figure I-40.

Figures I-47 and I-48 show the video monitor images and the A-scope peaks after a Kodak (K-2) filter has been installed in the receiver. Relative brightness of all the minerals remains essentially the same as described above for the ~~K-4~~ Kodak filter. Reappearance of the magnesium oxide block may be due in part to a cyclical variation in power. Gain is about 90X that used as a reference in figure I-40.

Figures I-49 and I-50 show the video monitor images and the A-scope peaks after a ~~Corning~~ Kodak 15g filter has been installed; similarly, figures I-51 and I-52 show signal strength after a ~~Corning~~ Kodak 16 filter has been installed on the receiver. In both sets of illustrations, the fluorite and both calcites are very weakly shown. Although the phosphate and the colemanite continue to show strongly, their peaks in figure I-52, 50 mv and 30 mv respectively, were registered at a gain more than twice that shown in figure I-42, where a Corning 3-73 filter was used, and more than 90X that used as a reference in figure I-40, where no receiver filters were used.

Decay time

Experiments designed to study the decay time of ~~the~~ luminescence were hampered by the requirement which limited the transmitter to operation below 40 percent peak power. Consequently, studies that were conducted were inconclusive.

Several minerals, including fluorite and calcite as well as a special luminescence pigment, were set up about 15 feet from the transmitter. With the transmitter turned off, a long wave mineral light, peaking at 3660 Å, was held about two inches from each specimen. A luminescence lasting about one second after removal of the mineral light was noted on the video monitor for the calcite specimen; however, the attempt to photograph the A-scope was not successful. No luminescence was noted when the experiment was repeated using the UV transmitter. This suggests that increased transmitter power would be most desirable if further studies of luminescence decay time is undertaken, particularly at distances longer than 15 feet. Moreover, it will be necessary to devise some sort of transmitter chopping mechanism which is synchronized with the A-scope photo recorder, particularly for some minerals whose decay constant exceeds the sweep interval.

Originally, it was hoped that by defocusing the transmitter, it would be possible to increase the size of the transmitter flying spot, thus, effectively increasing the number of passes the UV illuminated spot would make over the same subject area. Accordingly, it was hoped that luminescence would be built up in successive steps or passes of the UV illuminated spot. It was expected that a luminescing specimen bombarded by UV in this manner would impulse itself more strongly on the video monitor and A-scope than where the transmitter was focused and the scans were accomplished in the conventional manner. Unfortunately, when the transmitter was defocused, only the blank spot in the transmitter optics was imaged on the video monitor.

Modification of the output circuit from the image dissector tube may permit decay constants to be registered directly in the A-scope; it is planned that these circuit modifications will be completed before the beginning of the Phase II program.

Power

Except for brief periods throughout Phase I work, the transmitter operation was restricted to 40 percent peak power in order to avoid overheating and failure of critical components. This restriction was not serious during Phase I, although it would have been desirable to increase power during discrimination tests at 20 and 25 feet so that filters could have been used on the receiver without adversely effecting the signal-to-noise ratio.

In Phases II and III, however, filters will be used where subject distances are much longer and power requirements will, therefore, become more critical. In the following tests increased power was used to image weakly luminescent specimens; this series showed that additional information may be expected at high input levels. The transmitter was filtered with a Corning 57-54; the receiver with a Corning 3-73. Subject distance was 15 feet. Layout of specimens is shown in Appendix I-F.

Figures I-53 and I-54 show the video monitor images and A-scope peaks of seven specimens arranged as shown in Appendix I-F. Transmitter power is .25 ma at 20,000 volts. Only the phosphate and colemanite are imaged strongly.

Figures I-55 and I-56 show the video monitor and the A-scope, respectively, after the transmitter power has been increased to .5 ma at 20,000 volts. Both calcites, fluorite, and the magnesium oxide block can be seen clearly.

Figures I-57 and I-58 show the video monitor and the A-scope, respectively, after the transmitter power has been increased to 1 ma at 20,000 volts. Here, all specimens can be seen, including the willemite, which is indicated by a weak pip on the A-scope in figure I-58.

Future Work

Phase II

Phase II will be similar to Phase I procedures already described except that the tests will be conducted at night outdoors, bulk samples will be used, and meteorological conditions will be observed and recorded for correlation with the results. The samples as well as the transmitter-receiver will be immobile. Hopefully, circuit modifications, soon to be completed, will enable the study of decay time to be included in the Phase II program. Appendix I-G shows the setup which is being prepared at the Westinghouse plant at Friendship Airport, Baltimore.

Because large bulk samples (200-300 pounds) of minerals luminescing under long wave ultraviolet light were not readily available, it has been necessary to reduce the 2-1/2 by 5 feet bins, originally intended, to smaller trays (Appendices I-G and I-H) which are being constructed. Bulk samples of adequate size to fill the trays have been obtained. Originally, it had been hoped to arrange the samples in bins where specific amounts of non-luminescing contaminants would be added. However, because of limited amounts of available minerals, evaluation of luminescence of contaminated specimens will be accomplished by means of cardboard stencils cut to represent various percentages of contamination.

Phase II will begin on or about November 5; it is hoped that it can be completed in the one-week time specified in the original contract schedule. However, such factors as equipment performance and adverse meteorological conditions cannot be predicted. Also, elimination of extraneous light from the Westinghouse plant and the need for "moonless" nights may delay the schedule somewhat.

Phase III

Phase III is similar to Phases I and II except that the equipment will be mounted in a truck or a van to be supplied by the U.S. Geological Survey. Field localities will be visited where minerals luminescing under long wave ultraviolet light are present. Accordingly, a list of such localities within a radius of 200 miles from the Baltimore-Washington area is being compiled (Appendix I-I). These and other localities, that also may be suitable, are plotted on the index map shown in Appendix I-J. Prior to the start of Phase III tests in late November, as many of these localities as possible will be visited in order to evaluate their suitability.

~~It is assumed that the apparatus will be mounted in the vehicle in an immobile position; that is, the angles of ascension or depression can be changed only by changing the attitude of the entire vehicle.~~

It is assumed that the apparatus will be mounted in the vehicle in an immobile position; that is, the angles of ascension or depression can be changed only by changing the attitude of the entire vehicle. Thus, not only must quarry walls, road cuts, etc., be found which contain minerals luminescing under long wave ultraviolet light; in addition, these outcrops must be:

1. Accessible with a van or a truck,
2. Free from extraneous light,
3. Within a very few degrees above or below the attitude of the truck so that a crude ramp can be fashioned where necessary to bring the outcrops into the field of view of the apparatus.

PART II

PART II - SPECTRAL DISTRIBUTION OF ULTRAVIOLET STIMULATED LUMINESCENCE

by

William A. Fischer and David L. Daniels

Objectives

The principal objectives of this investigation are:

1. To provide data on which to base filter selection for use in studies evaluating the ultraviolet video-imaging system developed by the Westinghouse Electric Corporation (Part I, this report).

2. To provide a catalog of spectral-luminescence data for use in and adding to our basic knowledge of luminescent phenomena.

3. To study the effects of prolonged radiation on luminescing surfaces.

4. To study effects of temperature changes on luminescence.

General description of experiment

The basic experiment concerns the measurement of the spectral distribution and relative energy of luminescence (if any) resulting from ultraviolet excitation. To accomplish these measurements, energy from an illuminating source is passed through a prism monochromator and selected wavelengths impinged on the surface of the mineral or other spectrum. Reflected ultraviolet energy is removed by filtering and energy emitted by the specimen (luminescence) passed into a grating monochromator. Energy, issuing from the grating monochromator, is measured with a photometer and results presented in conventional chart form. The equipment is shown in figure II-1.

Instrumentation

The instrumentation consisted of six major components:

1. Source - Three sources were used intermittently in these experiments: a cathode ray tube (CRT), a deuterium lamp, and a mercury lamp. Most measurements were made using the mercury lamp. The cathode ray source consisted of special phosphor deposited upon the base of a copper block and incorporated into a standard one-inch CRT assembly. The emission curve for this tube is shown in Appendix II-A. It was found that the total energy emitted by this tube was low in contrast to other sources. This low level of energy, coupled with losses in the optical trains and the monochromators, produced a signal only slightly greater than noise level of the recording system. For this reason, the phosphor source was not used frequently in this investigation.

The spectral distribution of energy emitted from the deuterium source is shown in Appendix II-A. The energy flux from the deuterium lamp is approximately 40X that of the CRT source and is satisfactory for these experiments. Unfortunately, this source was only intermittently available for use in this experiment. The mercury source was a Cenco 87298 lamp which emits at the standard mercury lines. Energy levels were satisfactory for the experiment but the gaps between the emitted lines restrict the content of the resulting information.

2. A Model QPM-30 (Schoeffel Instrument Co.) quartz prism monochromator was used to select the ultraviolet wavelengths impinged on the surface of the materials being analyzed.

3. A clear glass filter was used to block transmission of reflected ultraviolet light at wavelengths below 3000 Å into a second monochromator. A Kodak K-4 filter was used to block reflection of light at wavelengths below 4600 Å. Curves approximating the transmission of these filters is shown in Appendix II-A.

4. An American Instrument Company monochromator, model 4-8400, was used to select the spectral components of the luminescent energy. This instrument is satisfactory provided it is fitted with an appropriate filter to exclude reflected ultraviolet radiation. (Being a grating-type monochromator, harmonics of the ultraviolet radiation are introduced into the output).

5. An Eldorado Electronics Model 210 photometer was used for measuring the output of the second monochromator. This photometer has a satisfactorily low noise level. However, the S-4 response of the photomultiplier tube, used in the instrument head, is not sensitive to all the ultraviolet spectrum being studied. This shortcoming was partly compensated by introducing sodium salicylate to the surface of the glass envelope of the tube; sodium salicylate is a phosphor sensitive to "short wave" ultraviolet light. This modification extended the sensitivity of the photomultiplier to wavelengths shorter than 3000 Å (Appendix II A).

Curves showing spectral distribution of energy from luminescing minerals (Appendix II A) were not corrected for spectral response of the photomultiplier.

6. Recorder - An attempt was made to record the output of the dual photometer by means of a Varian model G-10 automatic recorder. Results were not satisfactory and readings were made directly from the photometer and "hand" recorded.

Results

Results of this program, thus far, are itemized below;

1. The spectral distribution of UV-induced luminescence of 16 samples have been measured; these measurements are given in Appendix II-A.

2. These measurements have made possible the separation, by use of appropriate filters, of all mineral specimens thus far used in conjunction with the Westinghouse UV video-imaging system.

3. These studies have facilitated evaluation of the present measurement system and the development of plans for its improvement.

Plans

We plan to continue this program in much the same manner as at present but with significant improvement in instrumentation. These improvements will include:

1. Evaluation of a high pressure deuterium lamp as a source of UV illumination.

2. Modification of the photometer by substitution of high sensitivity photomultiplier tubes, and changing the receptors so that the tubes may be easily interchanged.

3. Acquisition of an appropriate amplifier-recorder system.

4. At such time that the various new components have been established as satisfactory, a clock-drive mechanism will be attached to the wavelength selectors of the monochromators so as to reduce the need for human attendance during the measurement process.

PART III

PART III - MEASUREMENT OF ULTRAVIOLET REFLECTANCE

by

William A. Fischer and Reinhold Gerharz

Objectives

The objectives of the ultraviolet reflectance measurement program are:

1. To obtain a general knowledge of the ultraviolet reflectance of natural objects to provide a basis for estimating power requirements of field instruments.

2. To evaluate the Beckman infrared spectrophotometer as a possible tool for further use in this program.

General description of experiment

The ultraviolet reflectance of samples of natural objects including rocks, minerals, and vegetable material, were measured with a spectrophotometer. Flux density of illumination was kept uniform throughout the 2000-4000 Å part of the ultraviolet spectrum by electronic adjustment of the entrance aperture of the spectrophotometer. As a result, spectral resolution diminishes with wavelength. Quantities of reflected ultraviolet from the specimens were measured with photomultiplier tubes sensitive to both UV and visible light. Thus, measurements shown on curves in Appendix III-A include both reflected UV energy and energy from induced luminescence.

Instrumentation

The instruments used consisted of:

1. A DK-1 Beckman infrared spectrophotometer equipped with an Ulbricht sphere.

2. A Beckman model 92680 deuterium source.

3. Photomultiplier readout sensitive to the entire output of energy not absorbed by the specimens (including both the reflected ultraviolet and any ultraviolet-induced luminescence).

4. A standard chart recorder

5. A magnesium oxide block used as a reflectance standard (considered 100% on reflectance curves shown in Appendix III-A.

Results

Results of this measurement program are:

1. Quantitative estimates of the reflectance of ultraviolet energy by various natural objects (see Appendix III-A).

2. A suggested method of approximating the spectral position of maximum absorption by observing the corresponding spectral position of maximum luminescence.

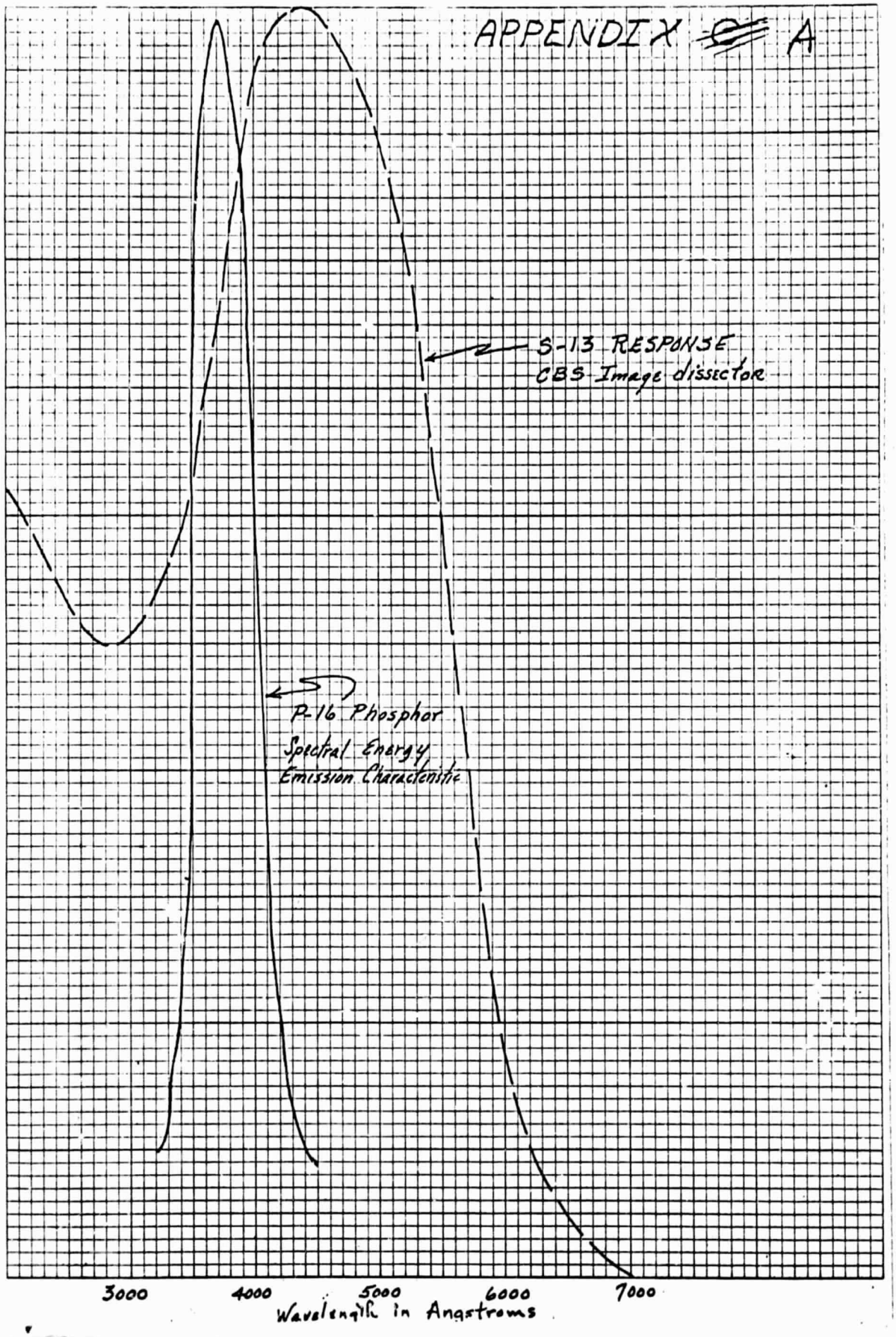
3. Demonstration of the inability of the system to resolve specific absorption lines in the UV spectrum.

Plans

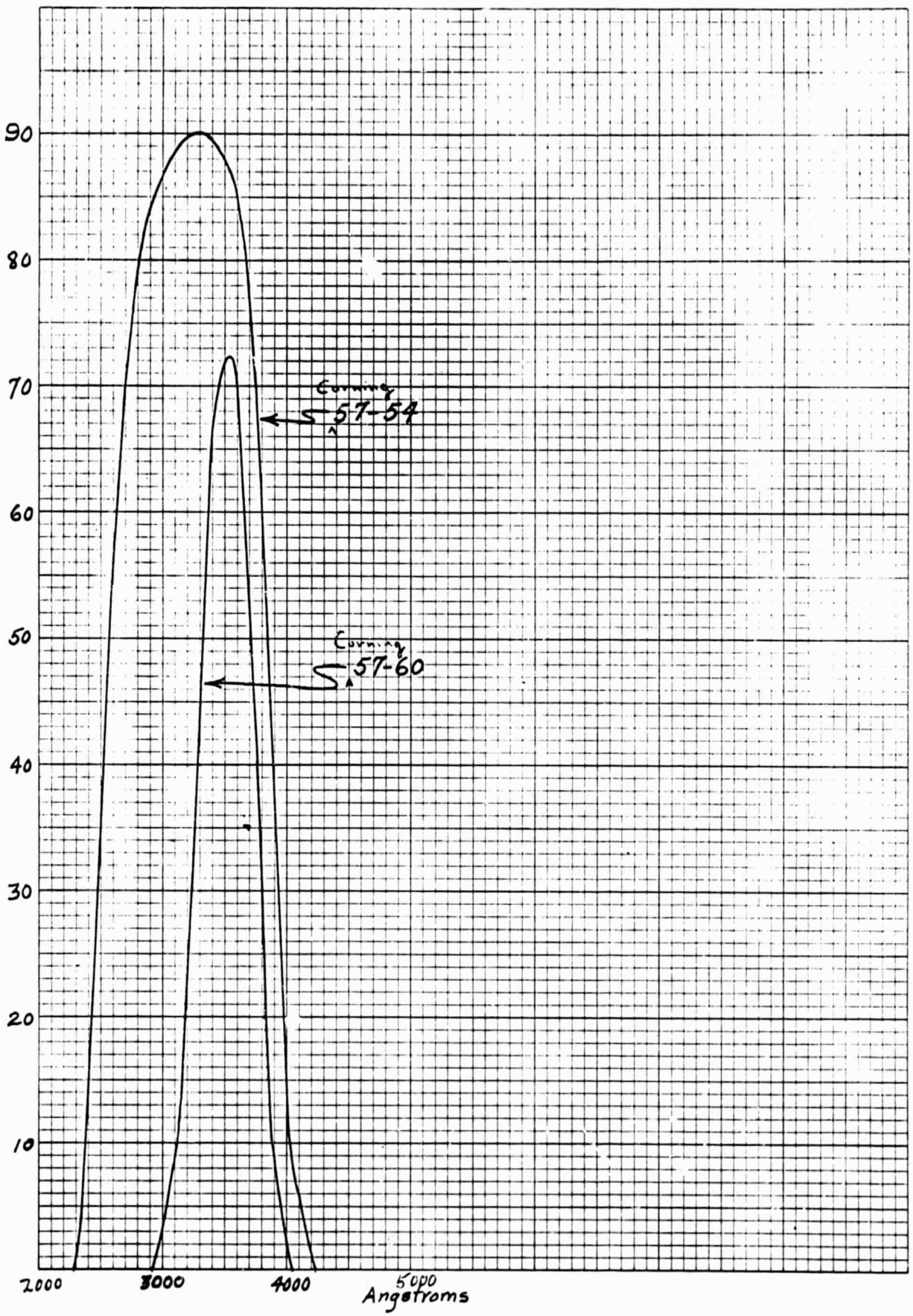
There are no plans to continue this experiment unless a need develops for additional reflectance data to use in the field evaluation of the Westinghouse ultraviolet video-imaging system (Part I, this report).

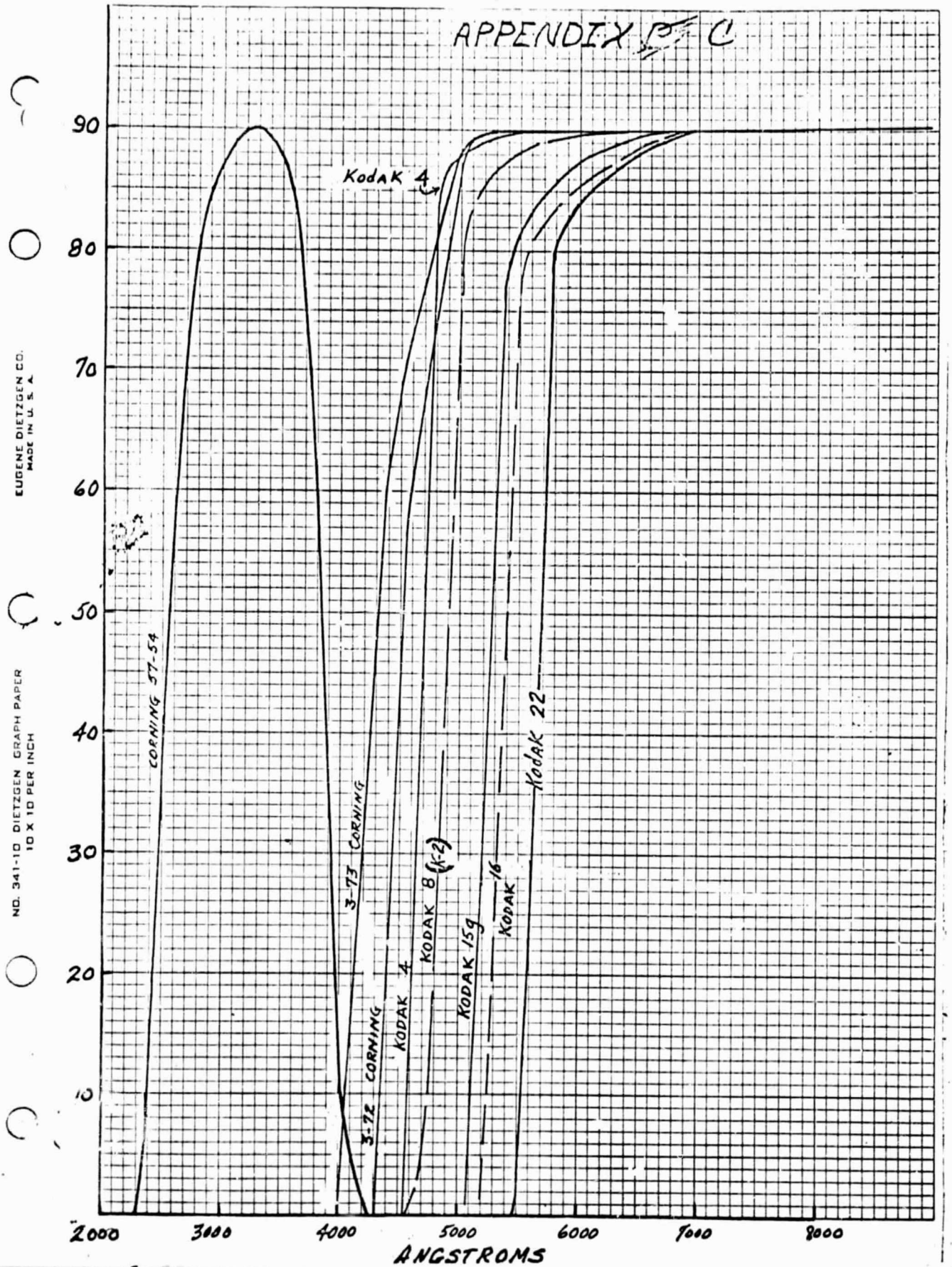
APPENDIX I

APPENDIX A


S-13 RESPONSE
CBS Image dissector
P-16 Phosphor
Spectral Energy
Emission Characteristic
Relative Radiant Energy
90
80
70
60
50
40
30
20
10
3000
4000
5000
6000
7000
Wavelength in Angstroms
EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 341-1 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

APPENDIX I-b




APPENDIX C
90
80
70
60
50
40
30
20
10
KODAK 4
CORNING 57-54
3-73 CORNING
3-72 CORNING
KODAK 4
KODAK 8 (K2)
KODAK 15g
KODAK 16
KODAK 22
2000
3000
4000
5000
6000
7000
8000
ANGSTROMS
EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 341-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

APPENDIX I-D

CALCITE
(West Va.)

CALCITE
(West Va.)

SCAPOLITE

FLUORITE

CALCITE
(West Va.)

APPENDIX I-E

1/	Scheelite	Quartz cobble	Willemite	Willemite & Franklinite	Calcium Larsenite
2/	Blue		Green	Green	Yellow
3/	4200				5375
					
4/	82a		201	199	C 6175

1/	Quartz face	Calcite	Scapolite	Fluorite
2/	(no scheelite showing)	Red	Yellow	Blue
3/			5450	4210
				
4/	82c	209	127	86

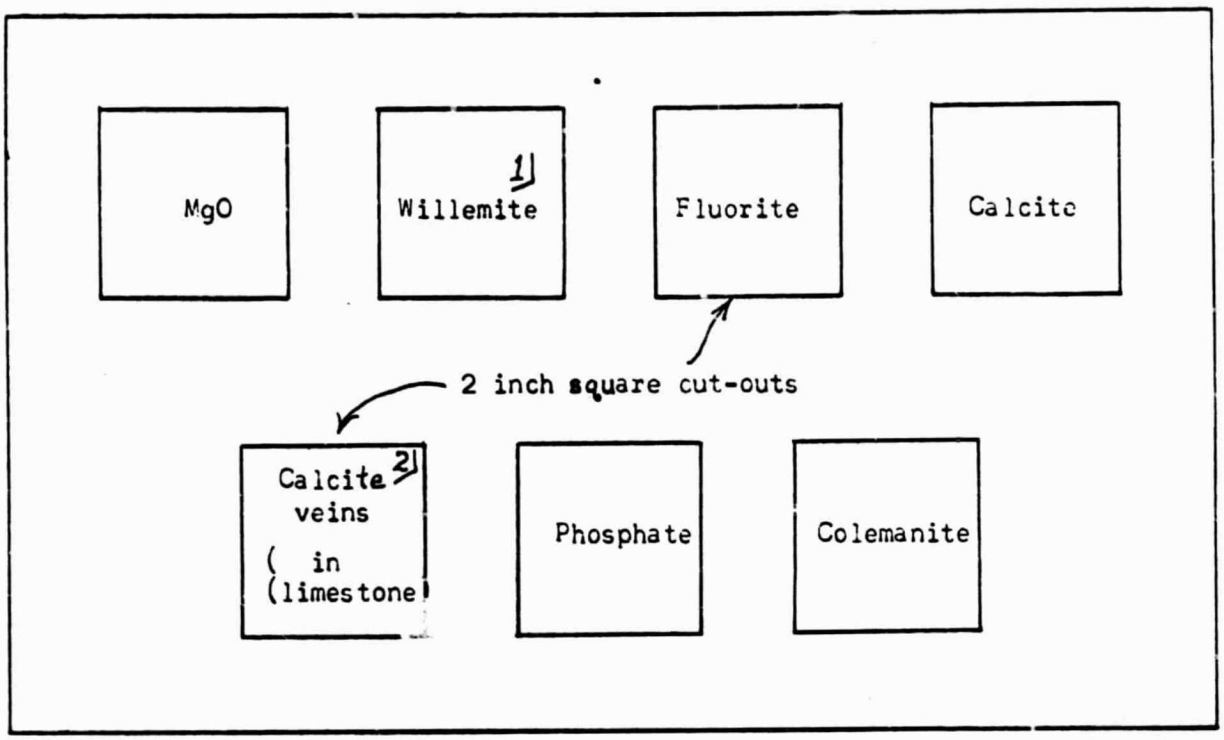
1/ Mineral.

2/ Color of luminescence.

3/ Wavelength (Å) of peak luminescence.

4/ Specimen number.

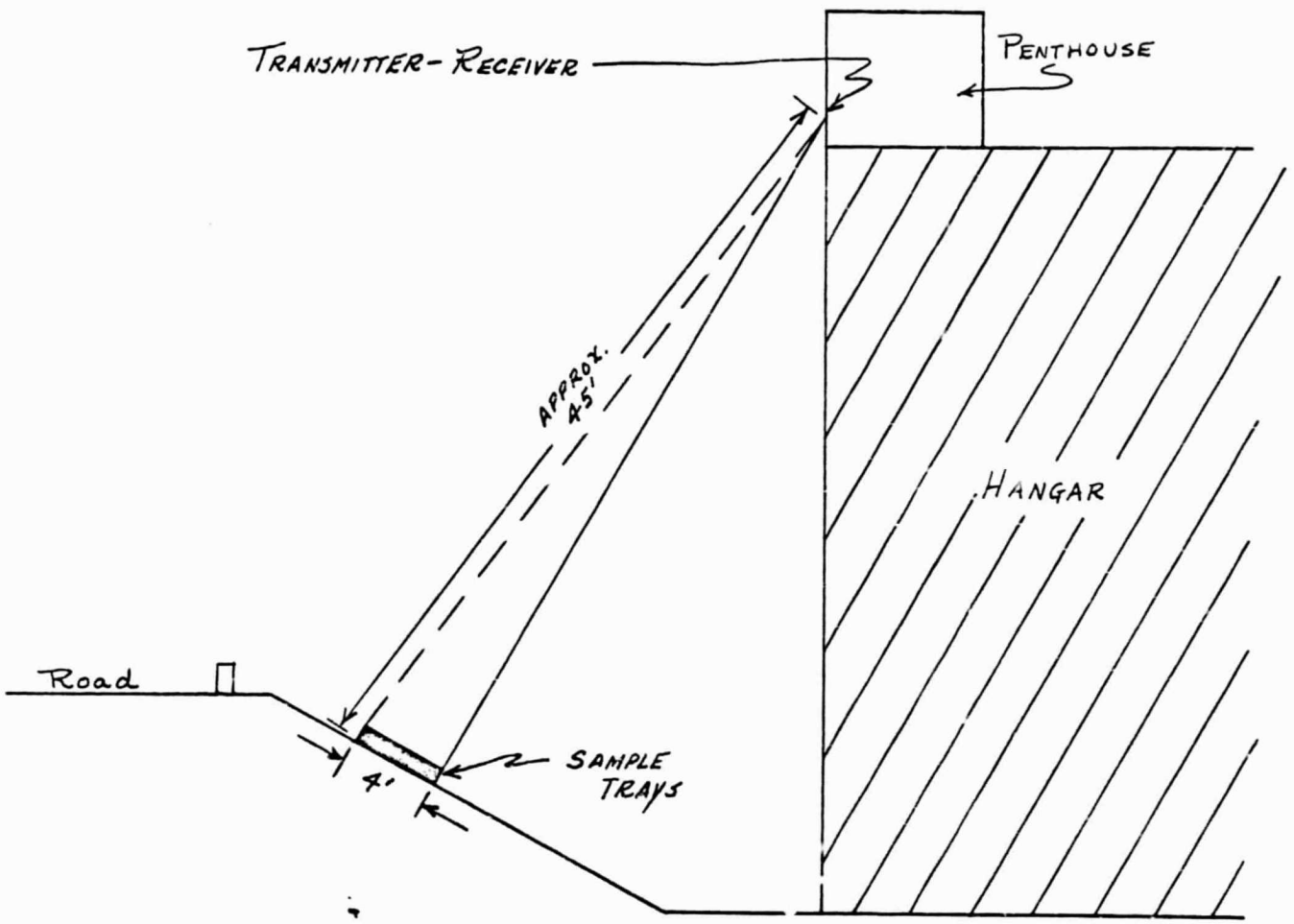
APPENDIX I-F



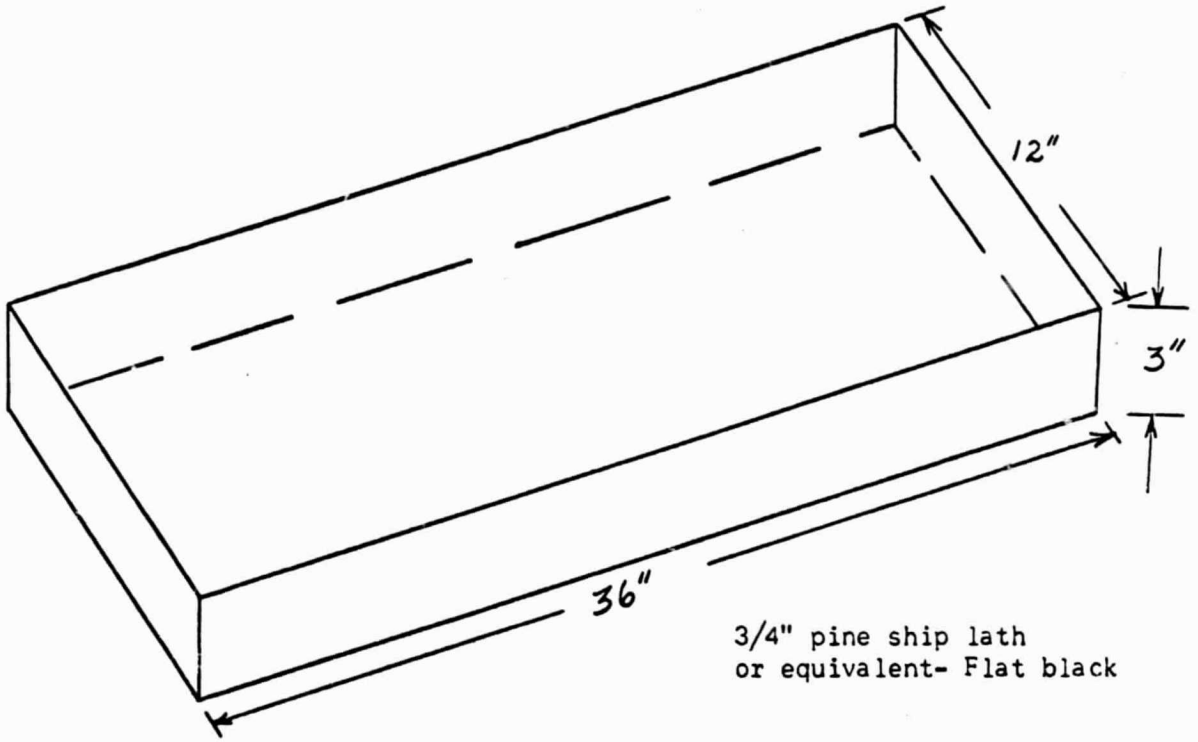
1/ Contaminated; only 15 to 20 per cent ~~fluoresces~~ luminesces under long wave ultraviolet light.

2/ ~~Fluorescing~~ Luminescing calcite veins occupy 30 to 40 per cent of the surface area.

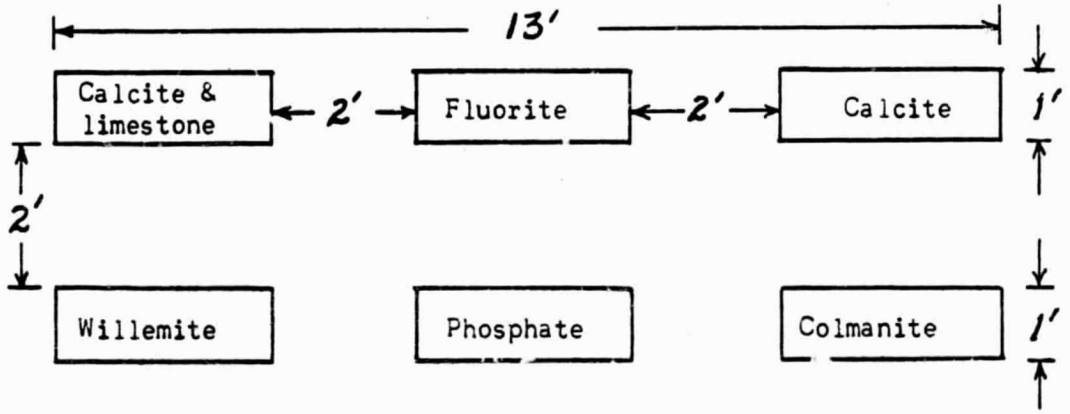
APPENDIX 1-G


TRANSMITTER-RECEIVER
PENTHOUSE
APPROX. 45'
HANGAR
Road
4'
SAMPLE TRAYS

APPENDIX I-H



SKETCH SHOWING SUGGESTED MINERAL TRAY, PHASE II

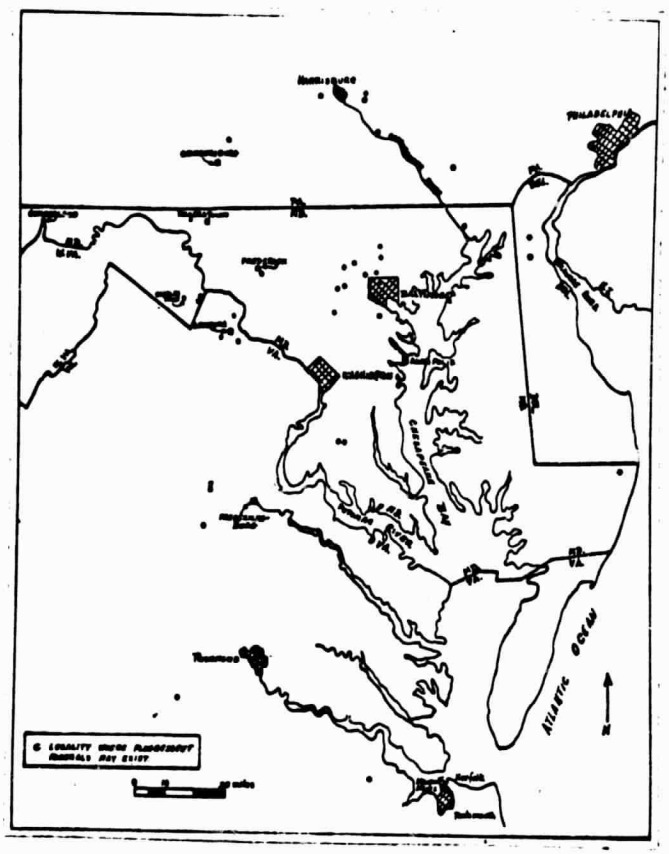


SKETCH SHOWING POSSIBLE LAYOUT OF TRAYS, PHASE II

APPENDIX I-I

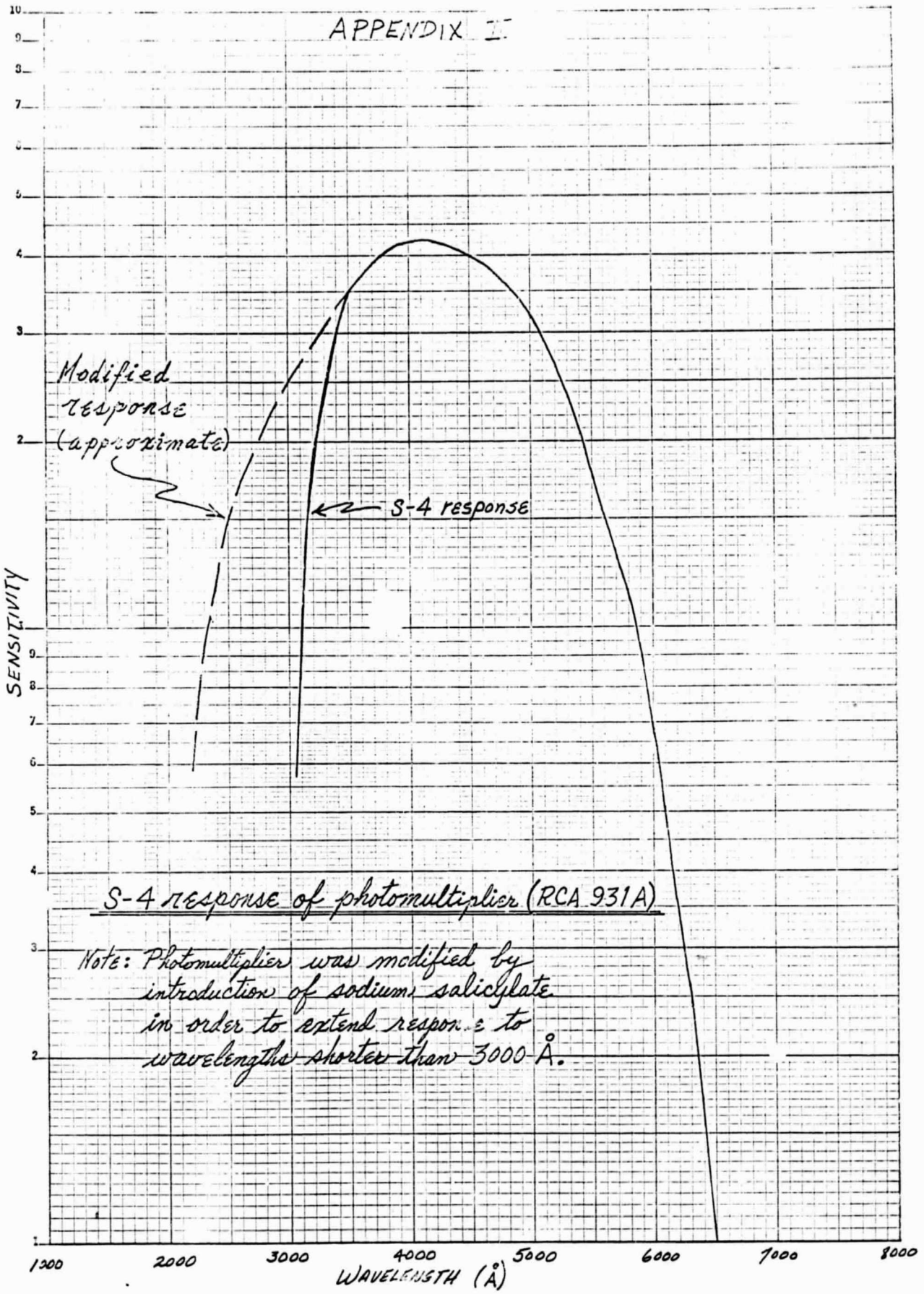
1. Harris Quarry, Jones Falls, Baltimore: Laumontite ($(Ca, Na_2)\ Al_2Si_4O_{12}\cdot 4H_2O$)
2. Delight, Maryland: Deweylite ($4MgO\cdot 3SiO_2\cdot 6H_2O$)
3. Severn River, Maryland (general locality): Amber
4. Bluemont (?), Maryland: Cerolite (?)
5. Barehill, Maryland: Deweylite ($4MgO\cdot 3SiO_2\cdot 6H_2O$)
6. Amelia Courthouse, Virginia: Fluorite (CaF_2)
7. Texas, Lancaster County, Penn.: Burkeite (?), Brucite ($Mg(OH)_2$ or $MgO\cdot H_2O$) at Wood's Mine, Deweylite ($4MgO\cdot 3SiO_2\cdot 6H_2O$) and serpentine
8. Dixon's Quarry, Newcastle County, Delaware: Deweylite ($4MgO\cdot 3SiO_2\cdot 6H_2O$)
9. French Creek, Penn: Marialite ($NaCl\cdot 3NaAlSi_3O_8$)

APPENDIX I-J



APPENDIX II

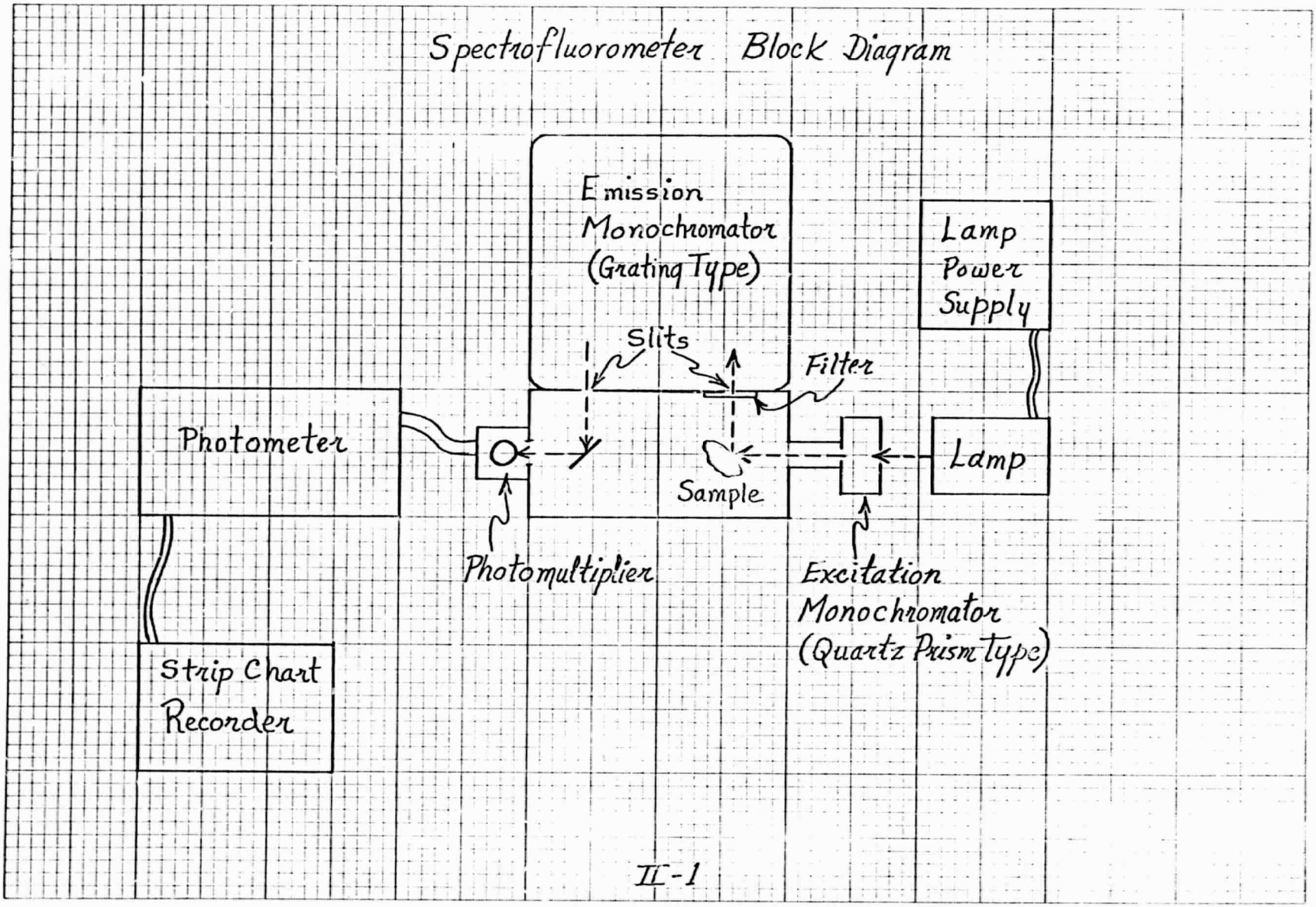
APPENDIX I



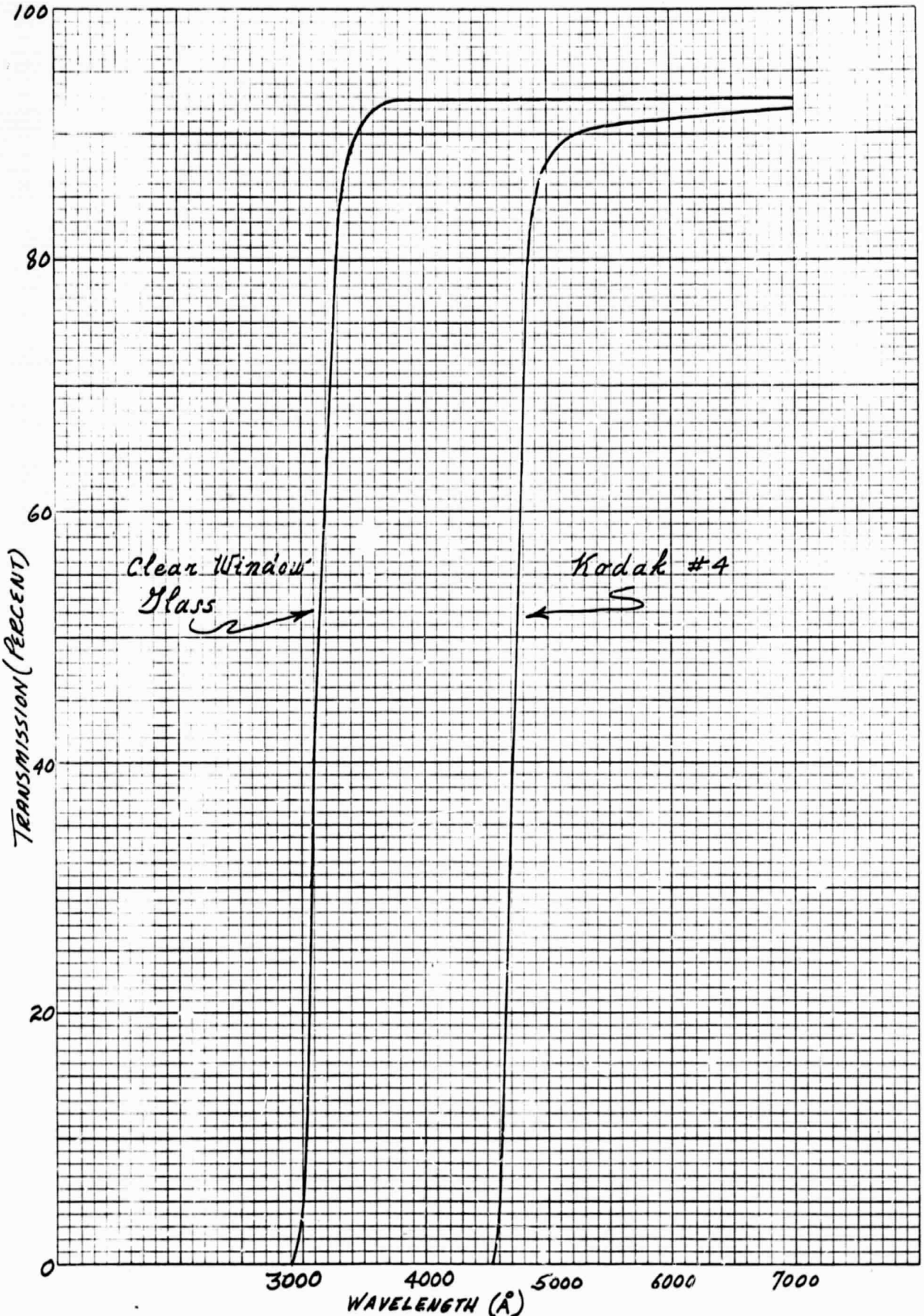
S-4 response of photomultiplier (RCA 931A)

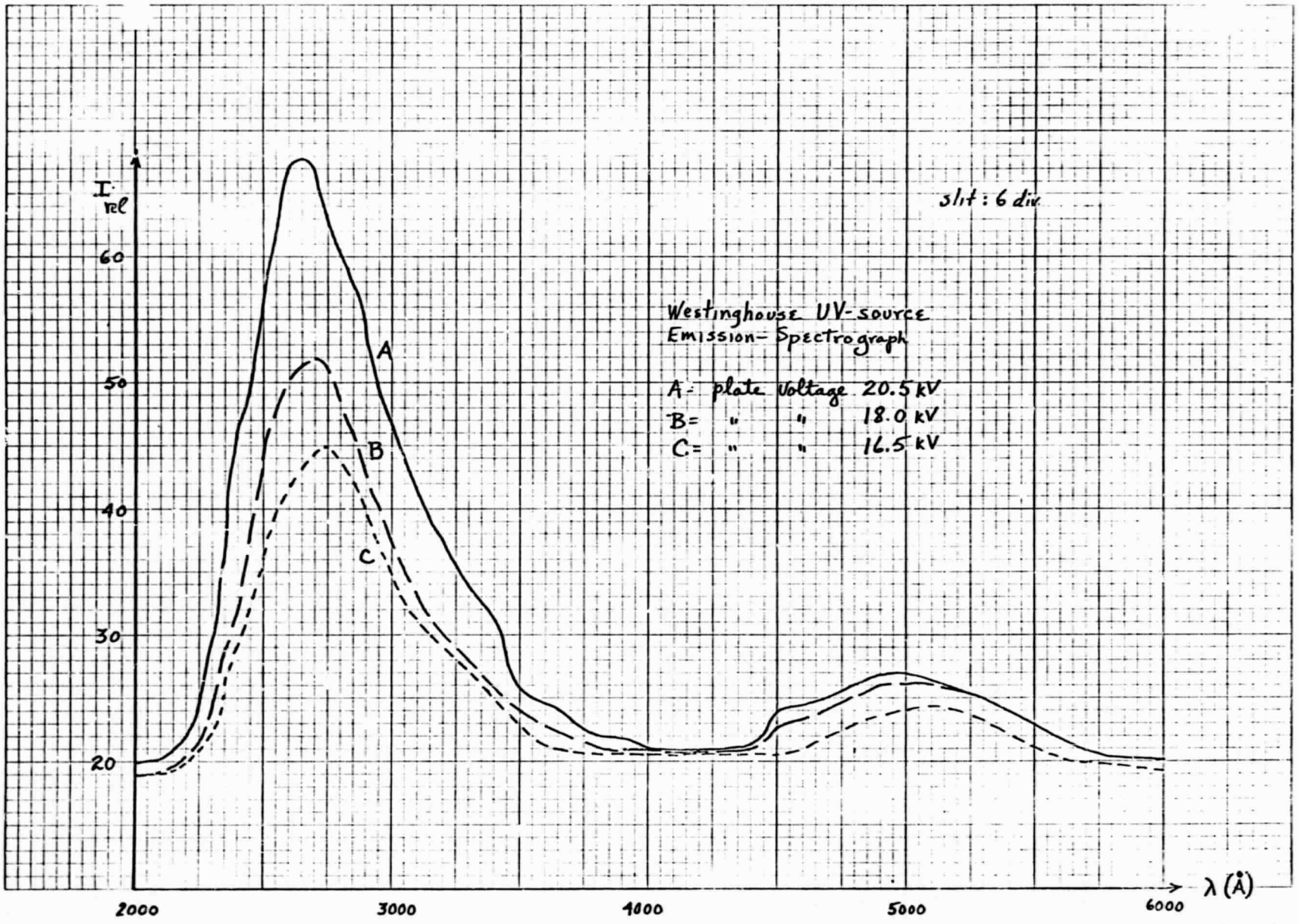
Note: Photomultiplier was modified by introduction of sodium salicylate in order to extend response to wavelengths shorter than 3000 Å.

Figure II-1. Diagram showing the ultraviolet source, quartz prism monochrometer, sample housing, grating monochrometer, and the photometer.

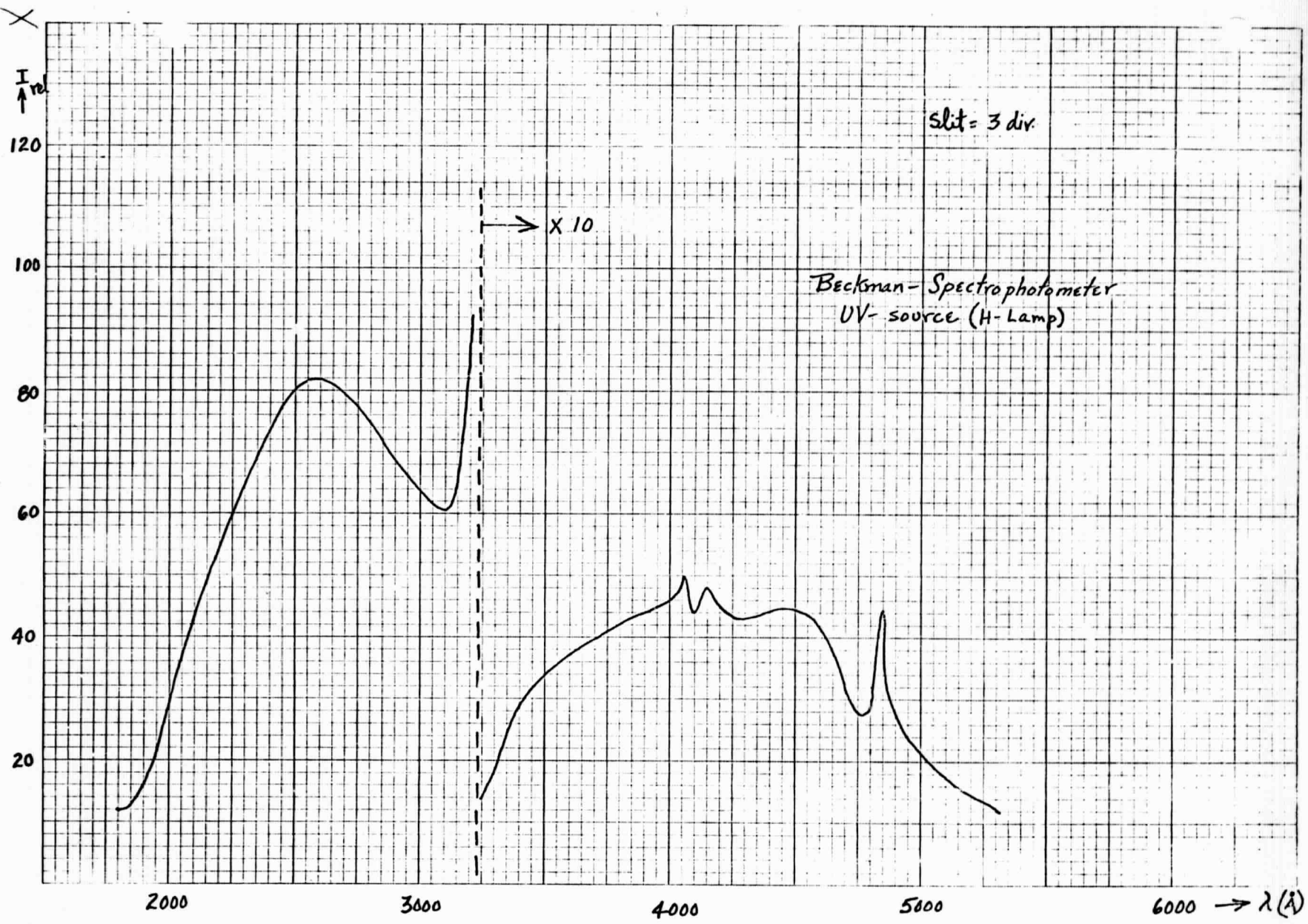


APPENDIX II-A



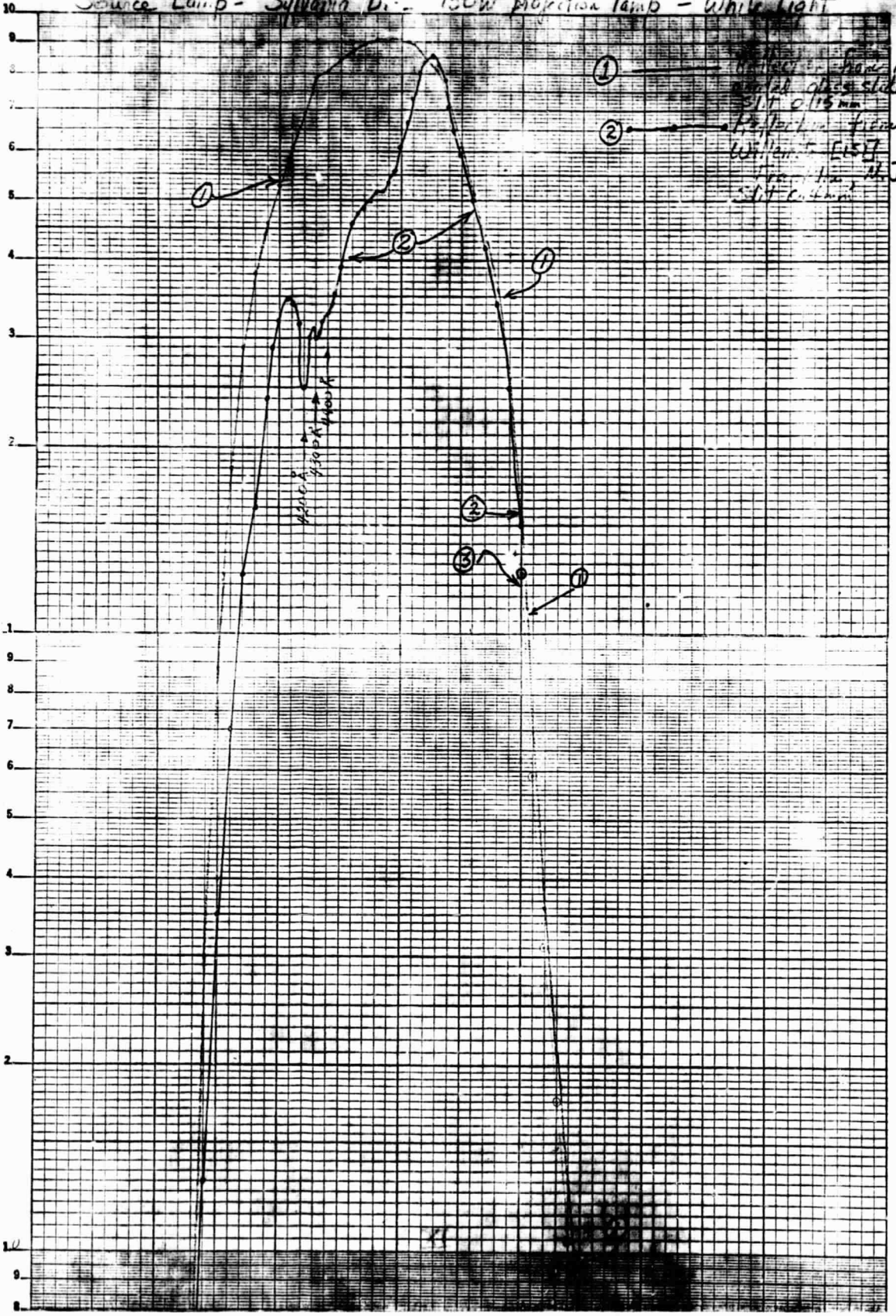

I rel
60
50
40
30
20
A
B
C
slit: 6 div.
Westinghouse UV-source
Emission-Spectrograph
A = plate voltage 20.5 kV
B = " " 18.0 kV
C = " " 16.5 kV
2000
3000
4000
5000
6000
λ (Å)

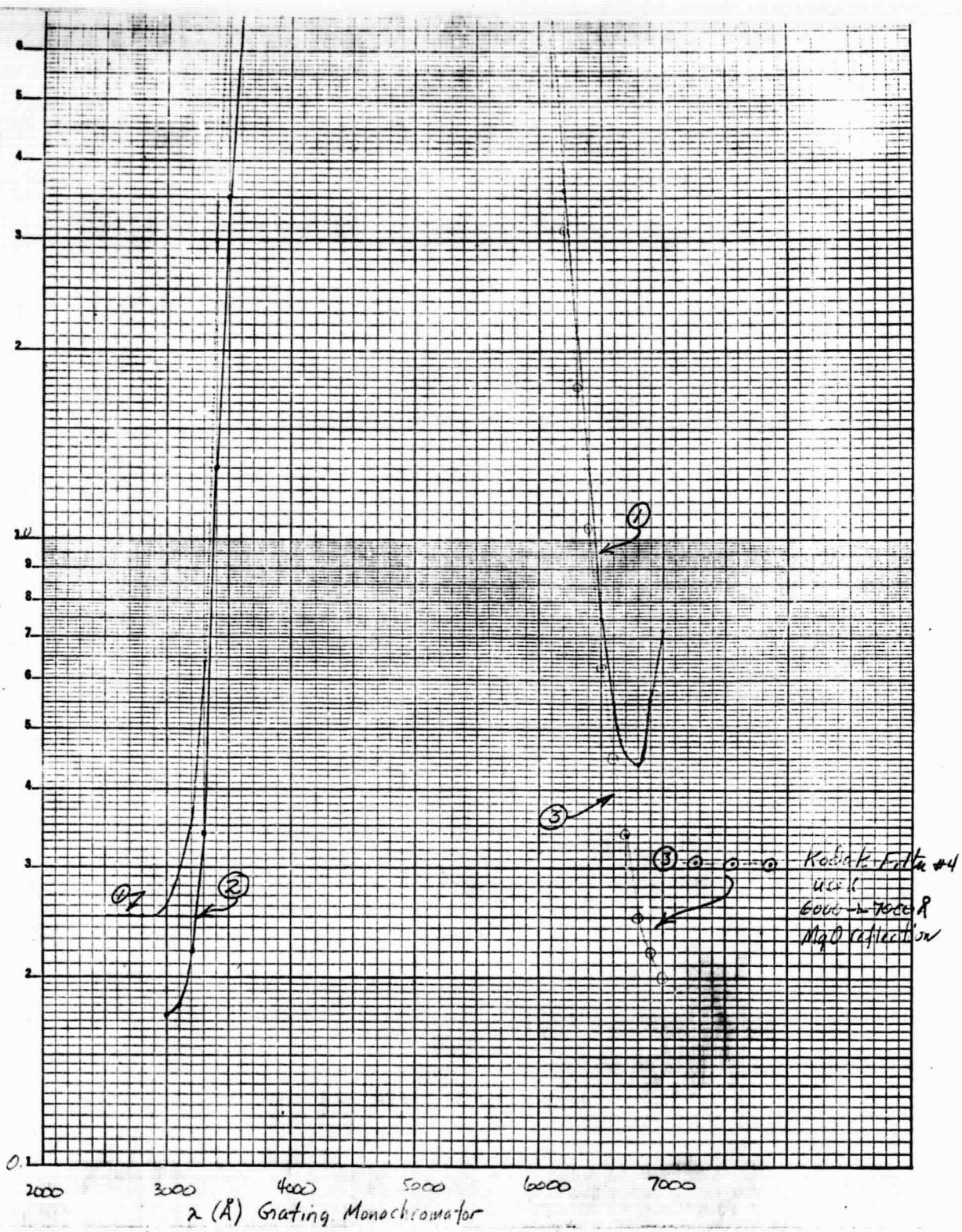
II-A

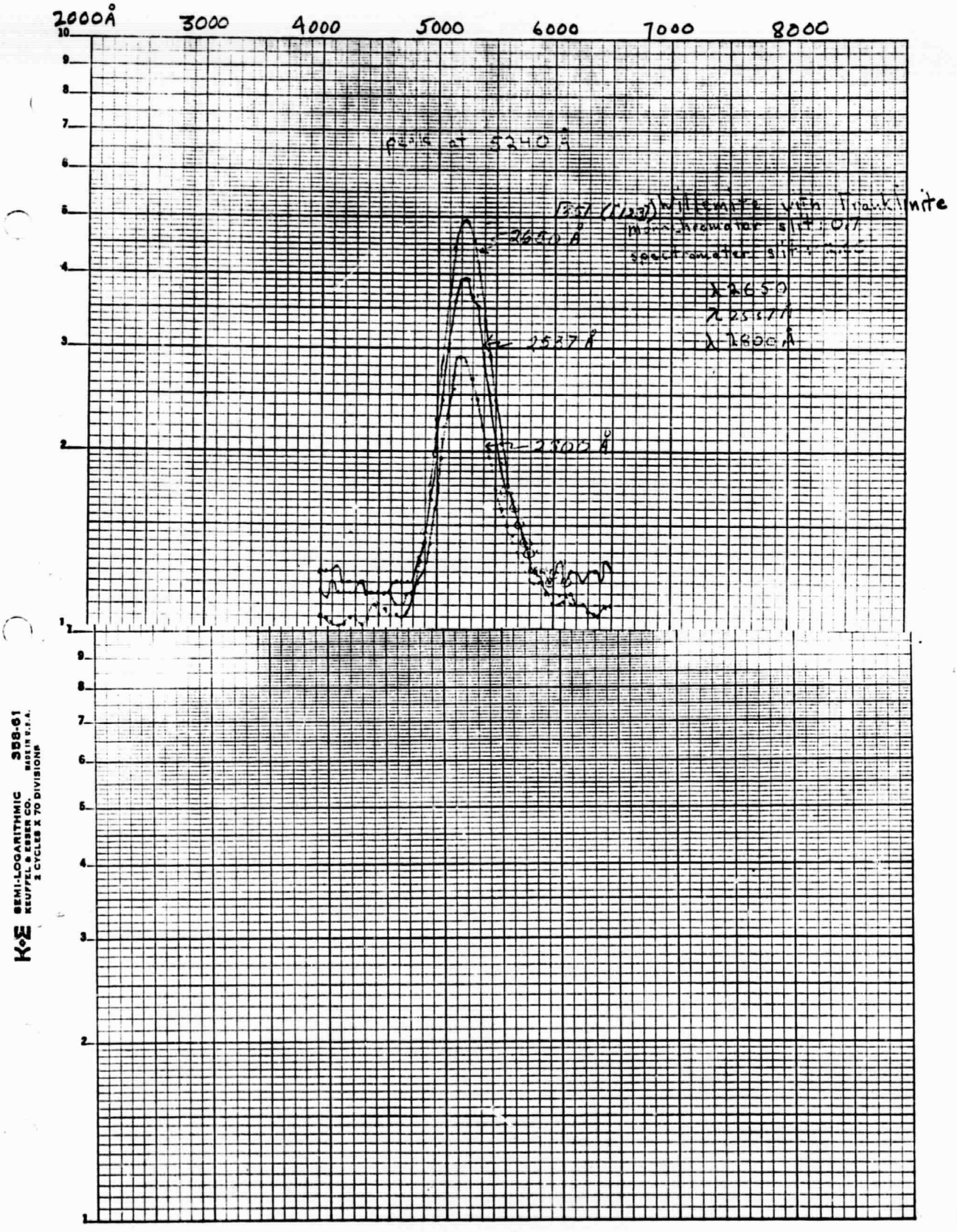


Reflection + Fluorescence Spectra — D. L. Daniels Sept. 20, 1964

Source Lamp - Sylvania DeLux 150W projection lamp - White light

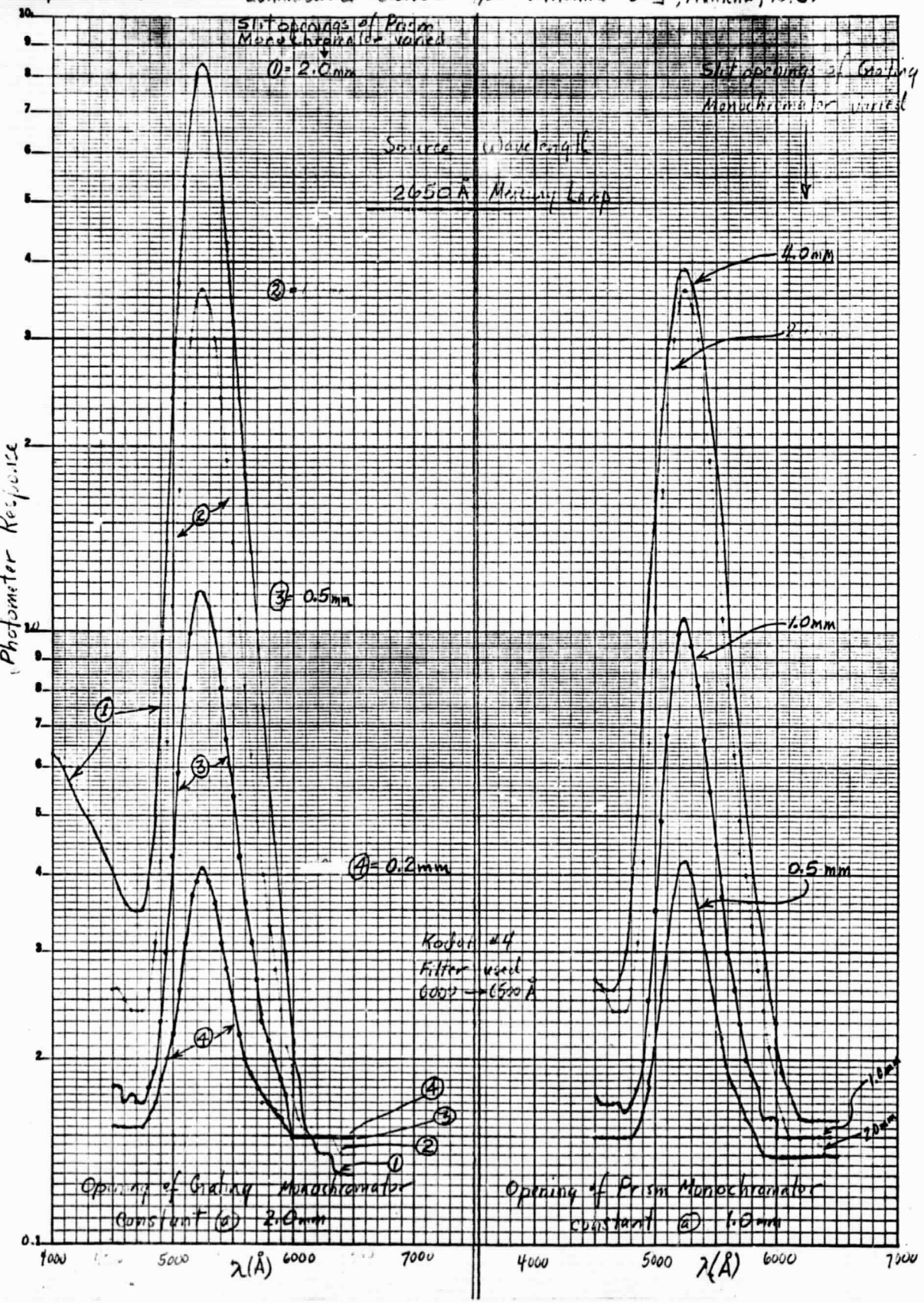



SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS
K&E
10
9
8
7
6
5
4
3
2
1
0.1
2000
3000
4000
5000
6000
7000
λ (Å) Grating Monochromator
①
②
③
Kodak Filter #4
used
600 – 700 Å
MgO reflection


2000Å
3000
4000
5000
6000
7000
8000
10
9
8
7
6
5
4
3
2
1
R's at 5240 Å
2650 Å
2537 Å
2503 Å
λ2650
λ2537 Å
λ1850 Å
K&E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS

D. L. Daniels
~ Sept 18, 1964

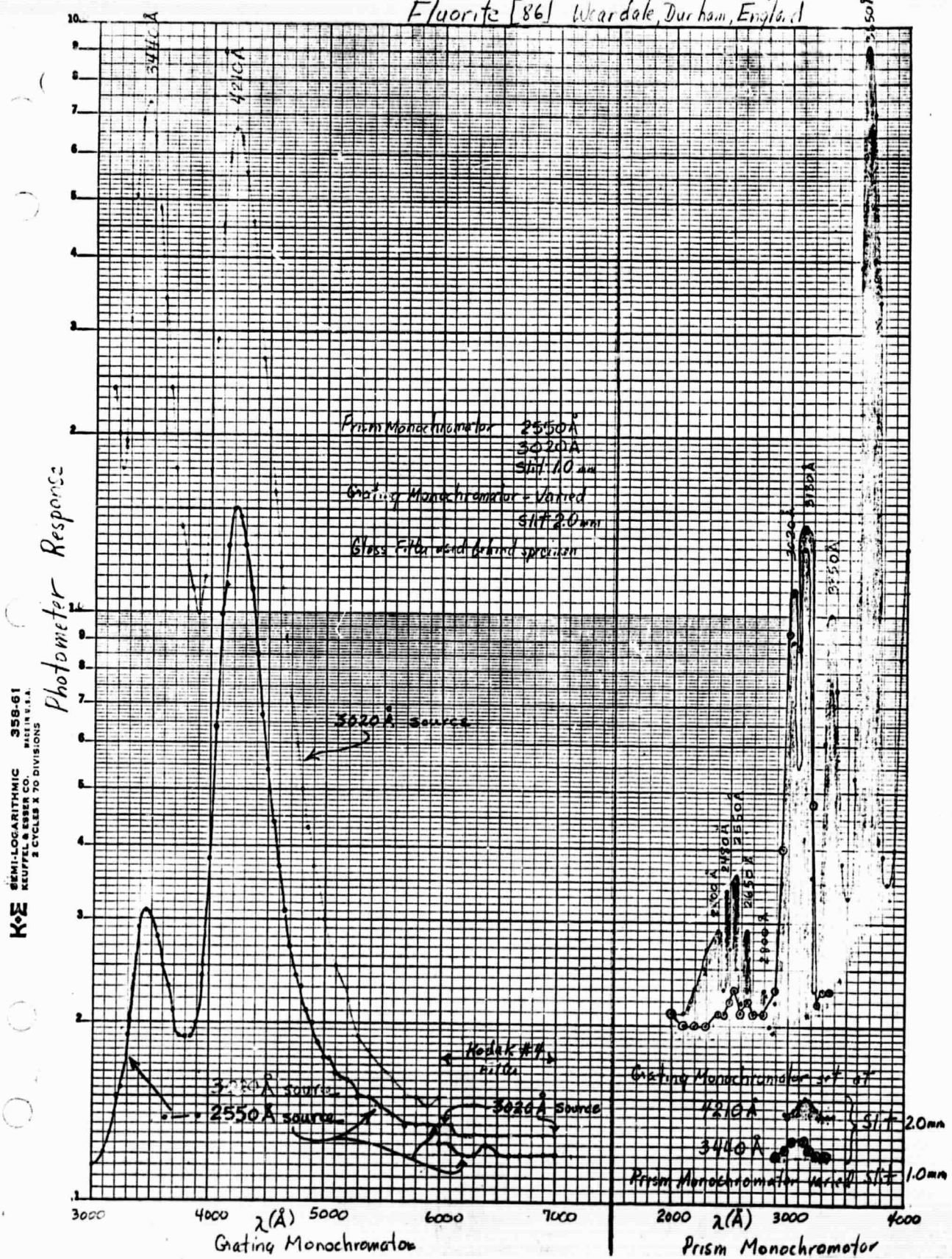
Effects of change in slit widths upon the shape of Luminescence curves for willemite [151], Franklin, N.J.



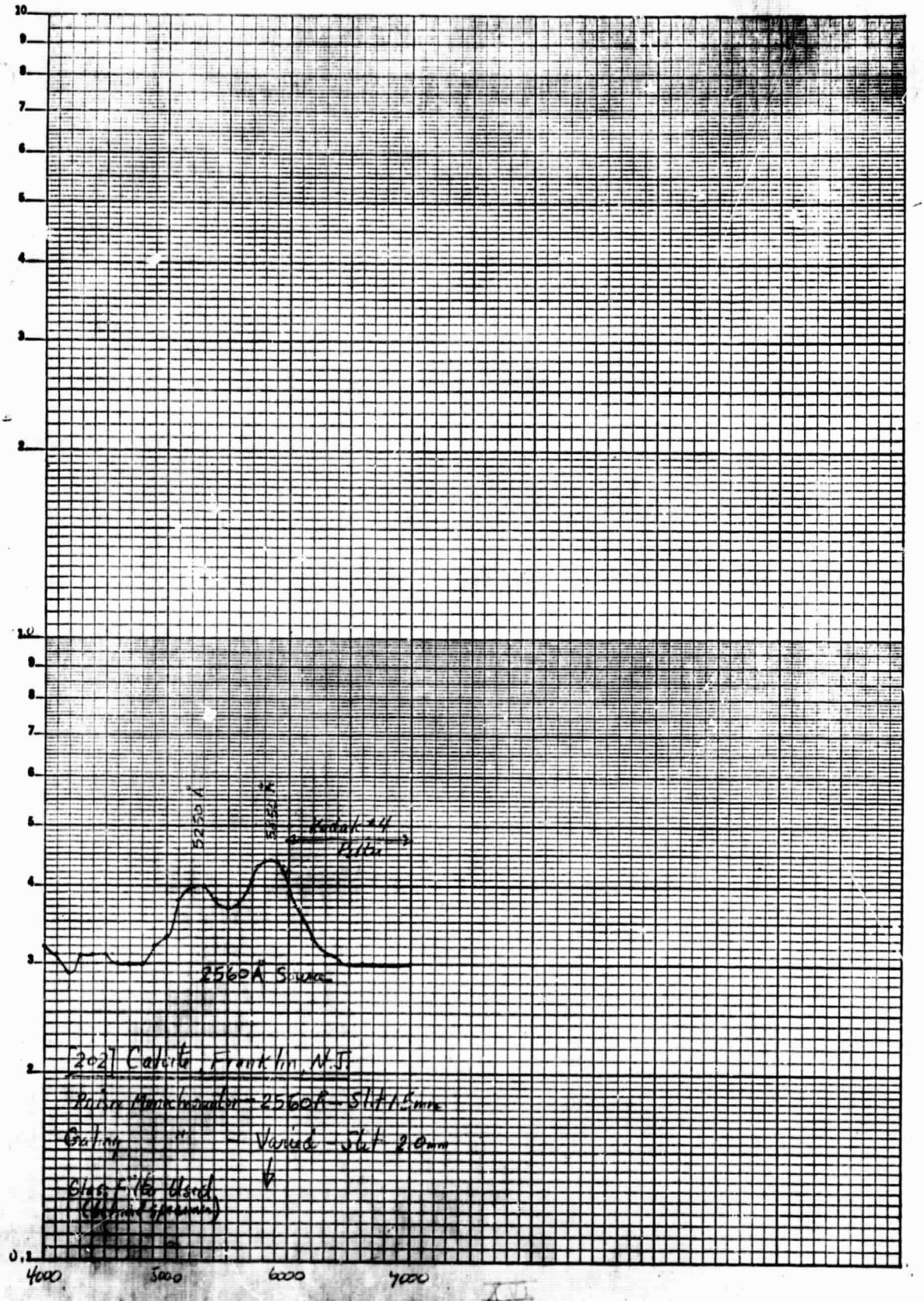
K&E 358-61 SEMI-LOGARITHMIC KEUFFEL & ESSER CO. MADE IN U.S.A. 2 CYCLES X 70 DIVISIONS

D. L. Daniels ~ Sept. 16-17, 1964

Fluorite [86] Weardale, Durham, England



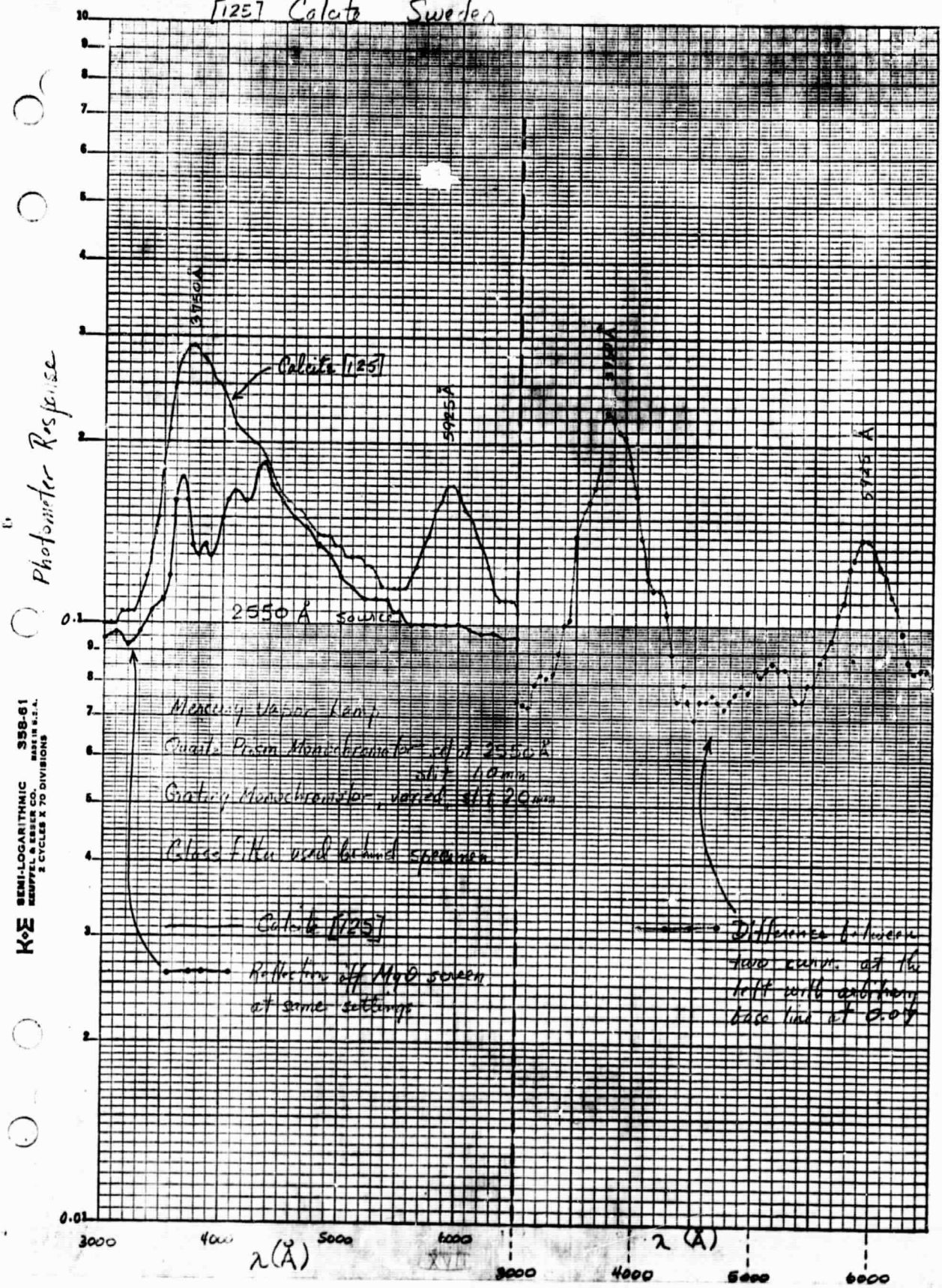
D. L. Deniels, Sept. 14, 1964



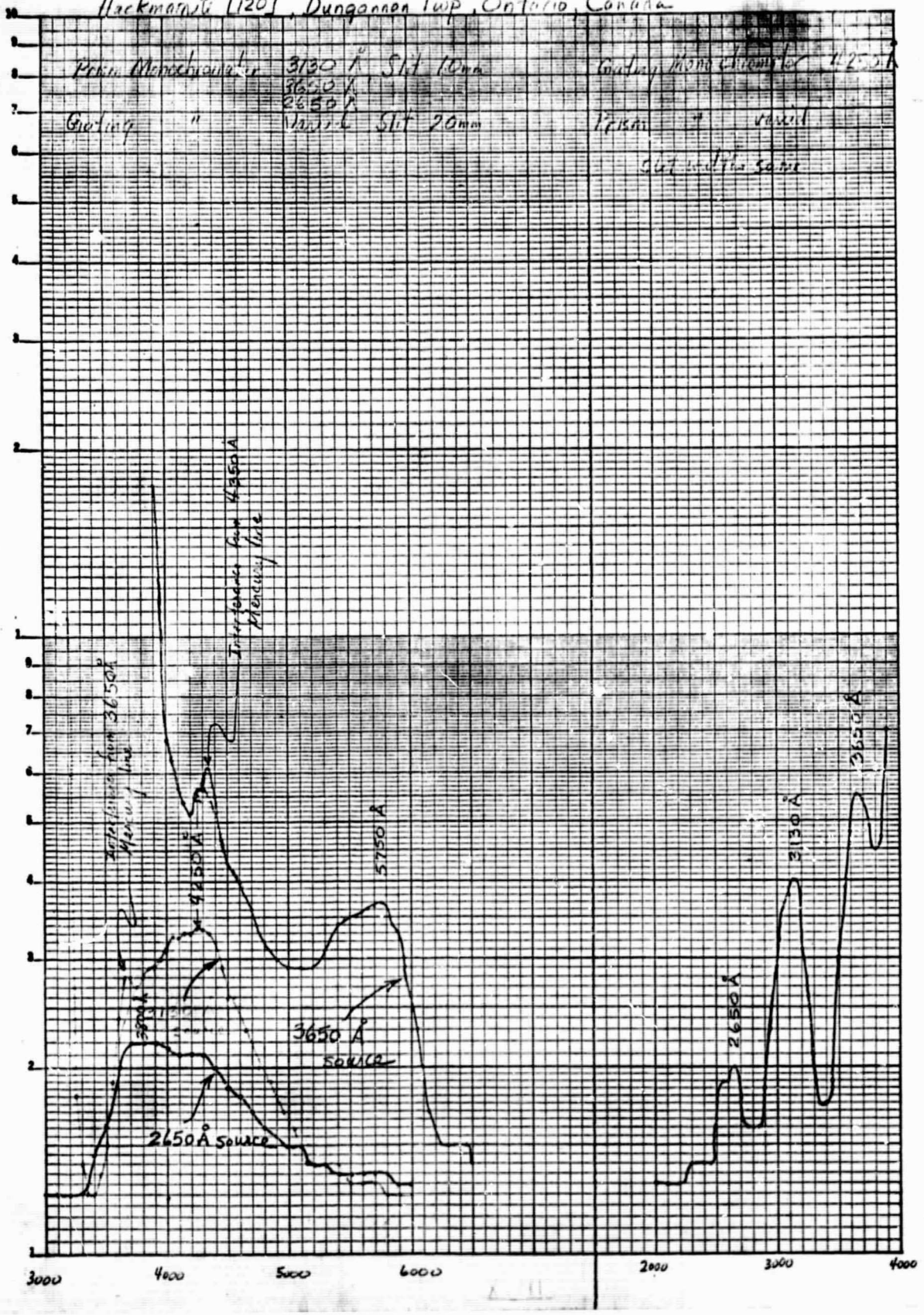
KE BERI-LOGARITHMIC 320-01
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS

XII

D. L. Daniels, Oct. 1, 1464

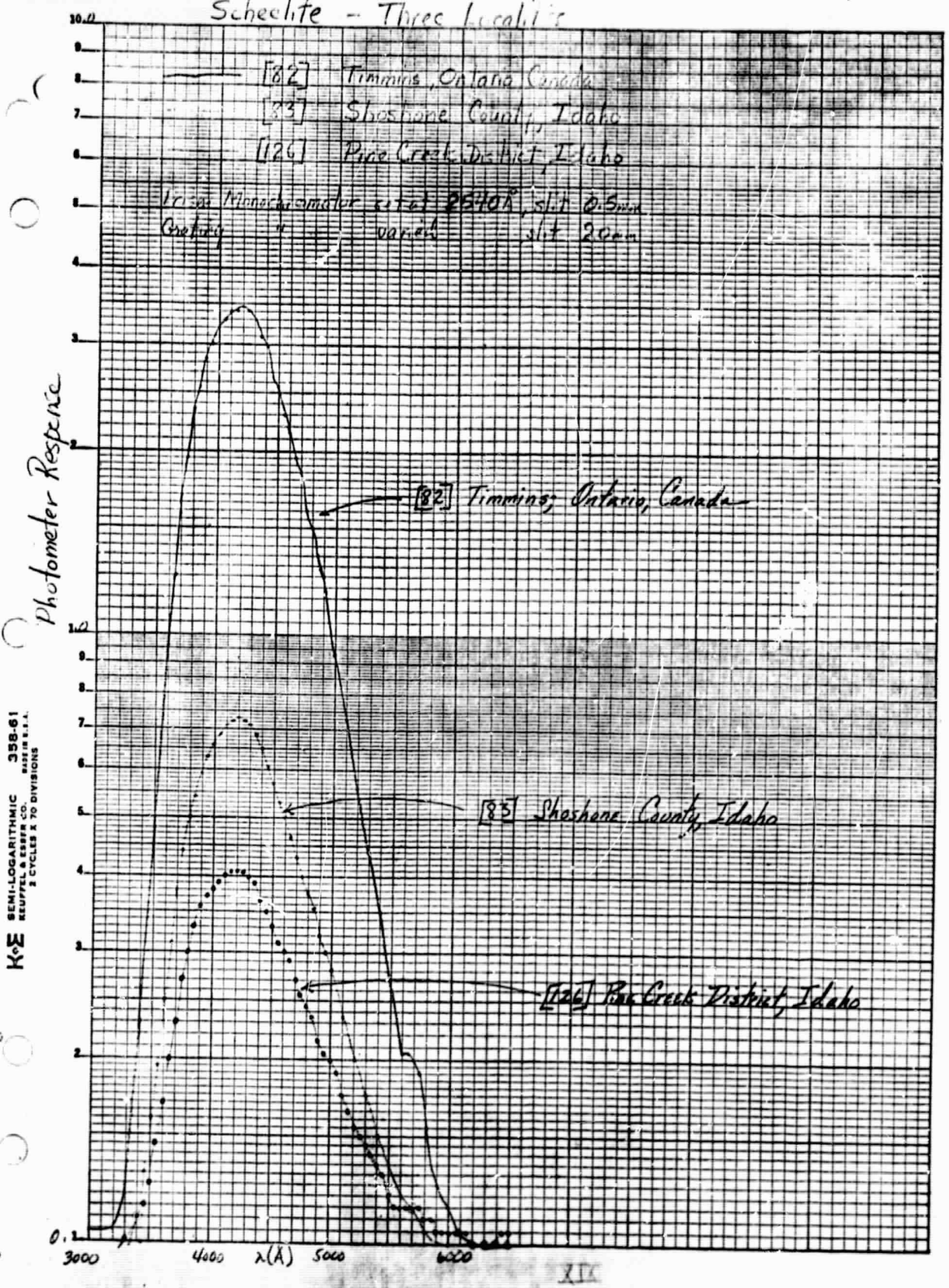


D. L. Daniels, Sept. 22, 1964



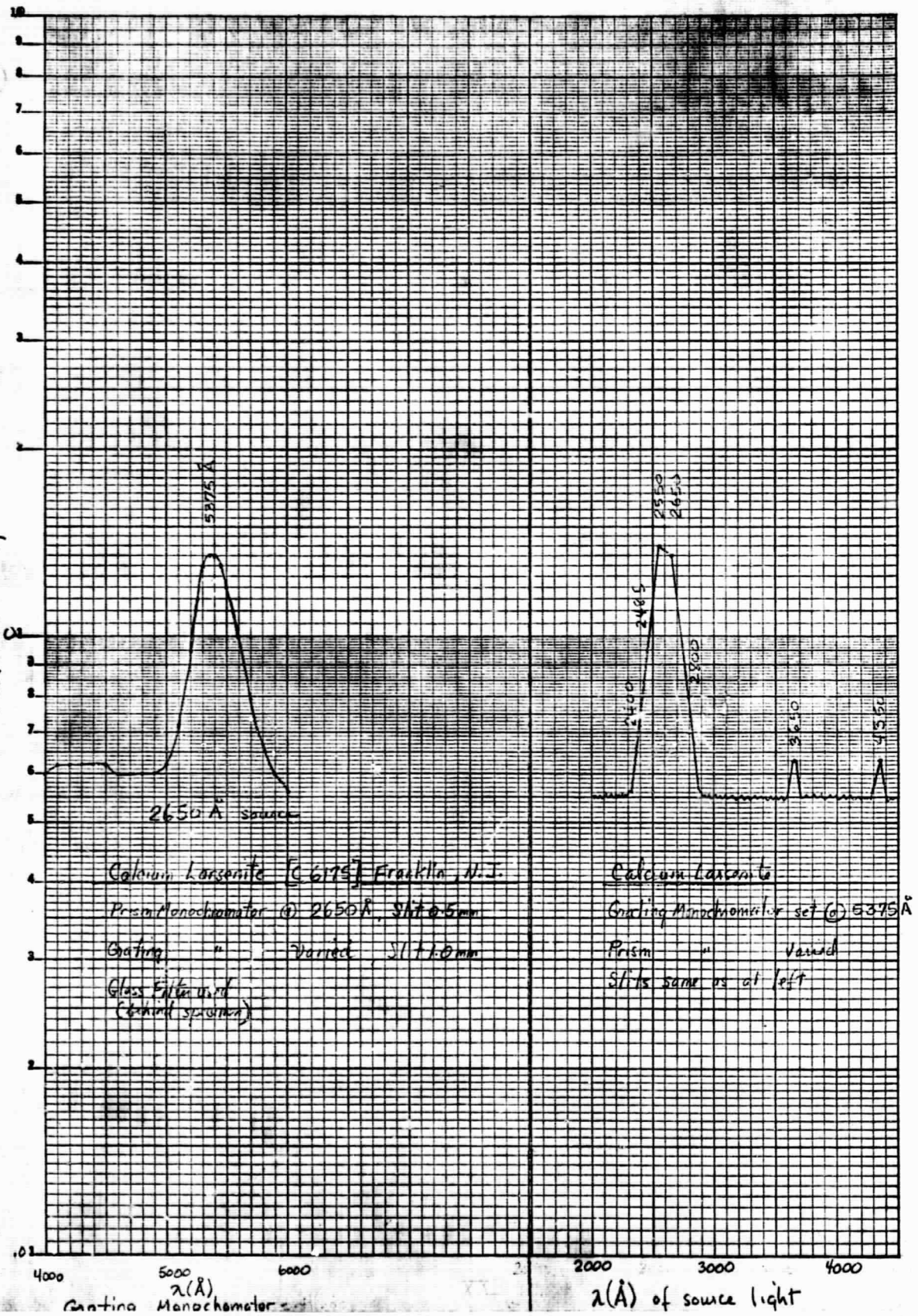
K&E SEMI-LOGARITHMIC 358-61 KEUFFEL & ESSER CO. MADE IN U.S.A. 2 CYCLES X 70 DIVISIONS

T. L. Dannick, Oct 2, 1964

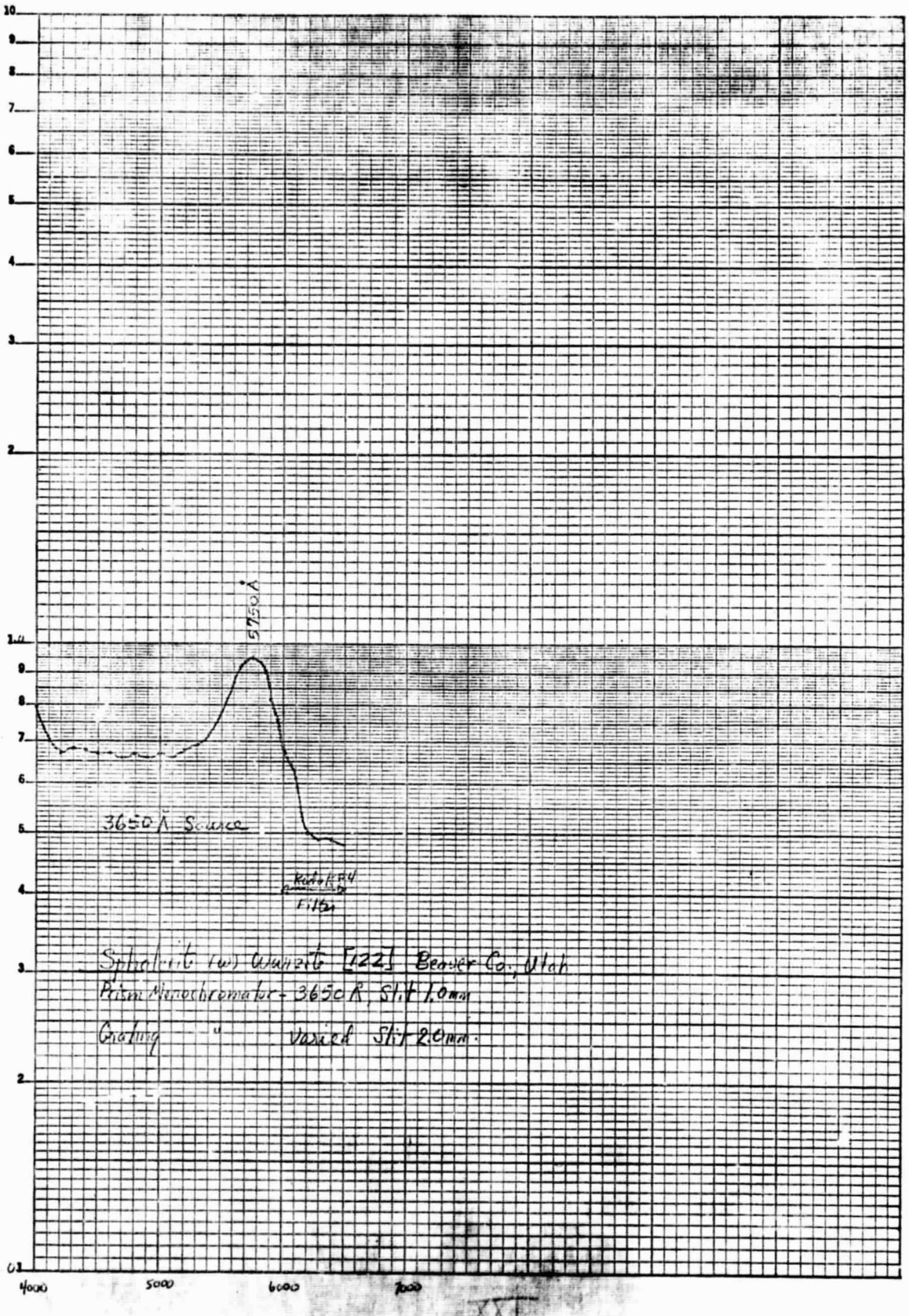


XIX

D.L. Domicks Sept. 11, 1964

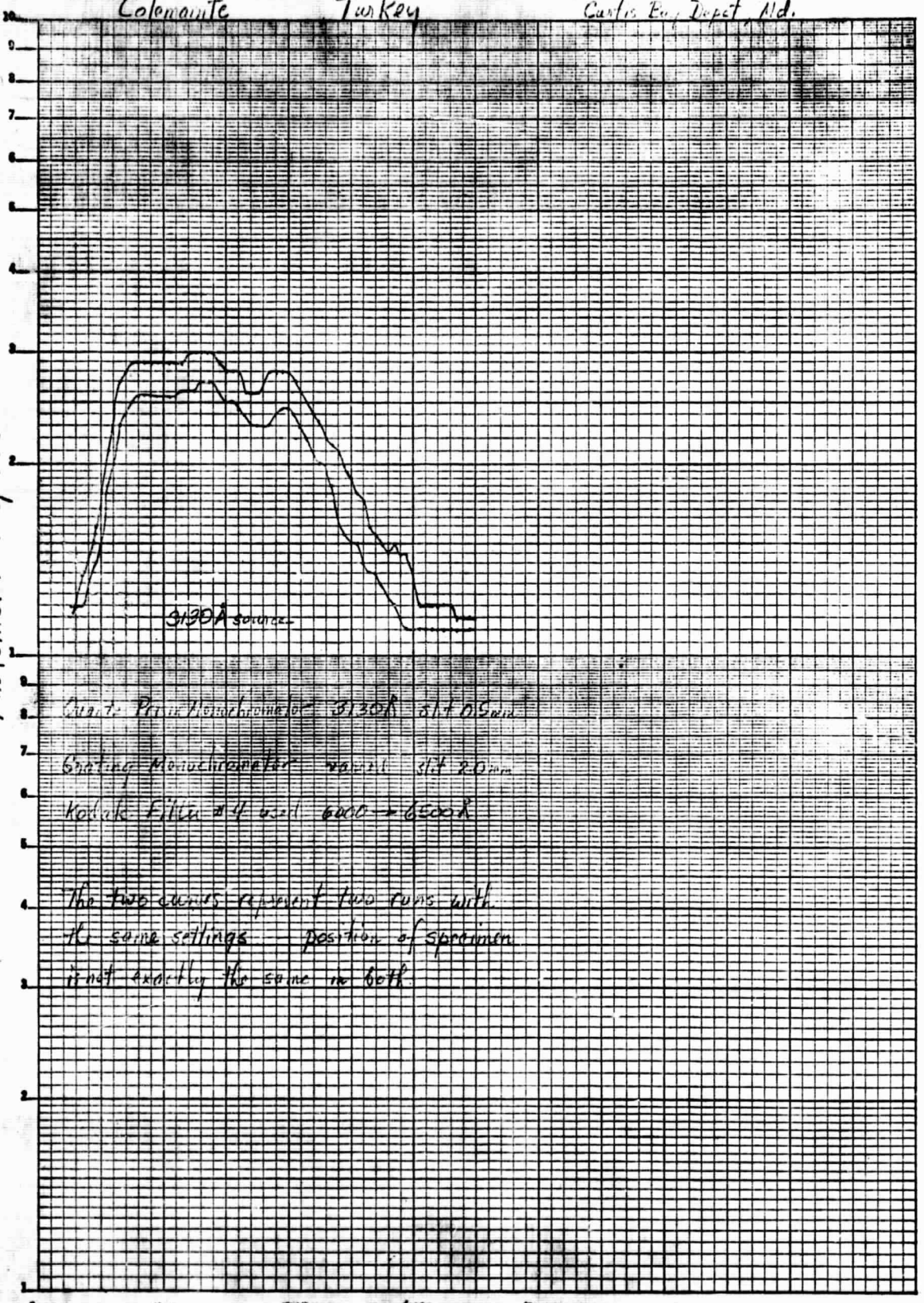


D. L. Daniels, Sept. 15, 1964



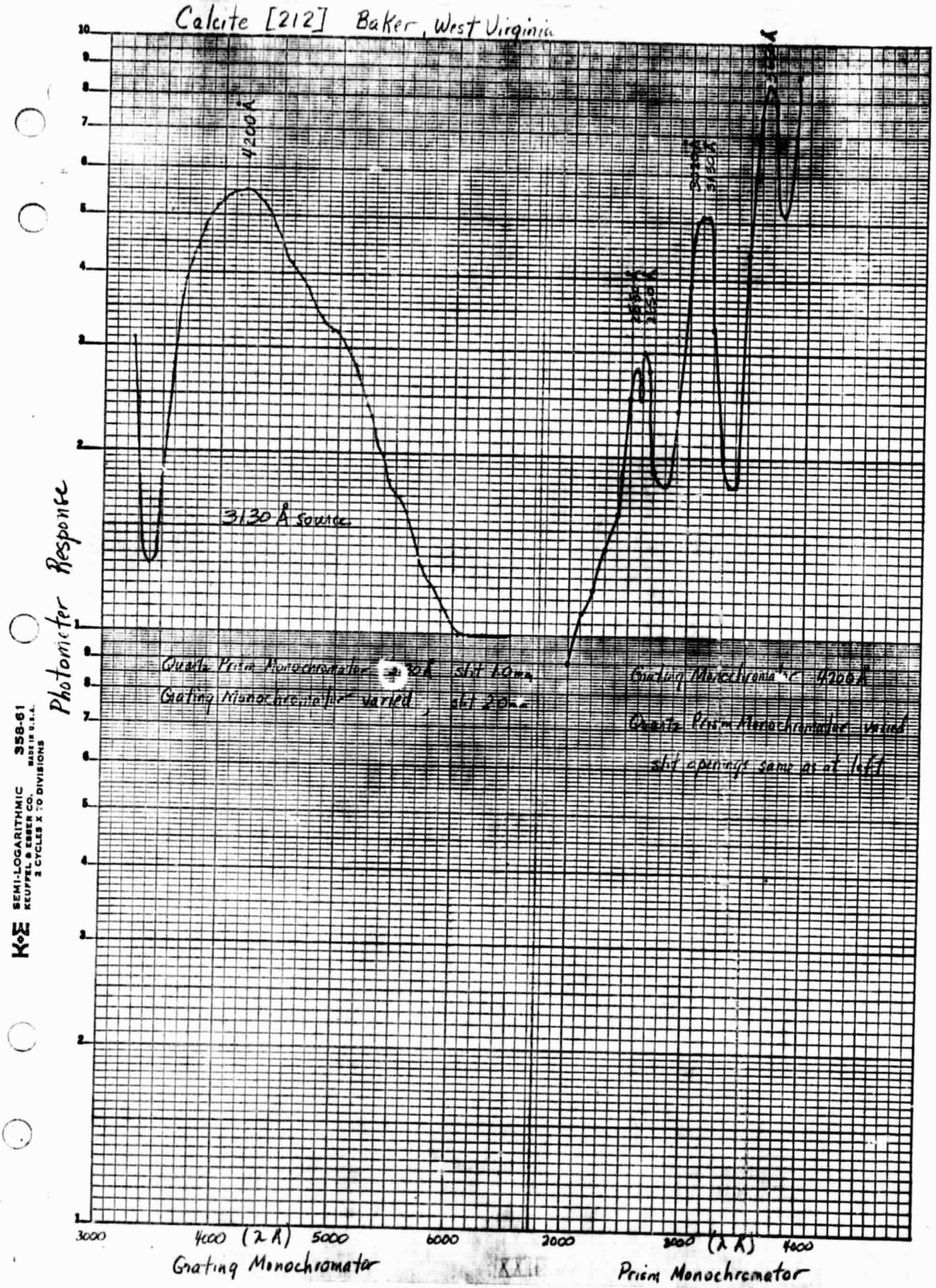
D. L. Daniels 10-16-64

Colemanite Turkey Curtis Bay Depot, Md.

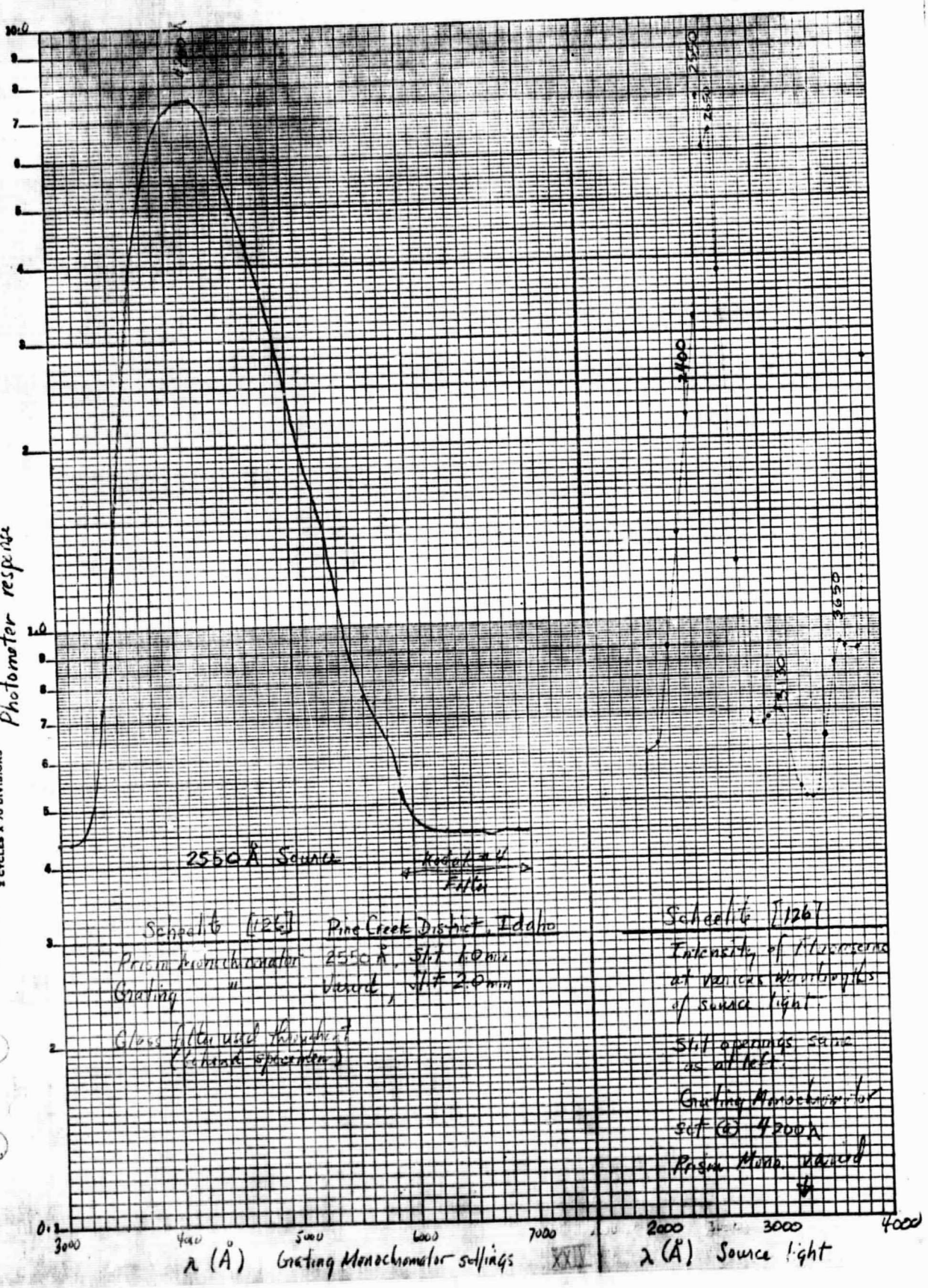


K&E SEMI-LOGARITHMIC 358-61 KEUFFEL & ESSER CO. MADE IN U.S.A. 2 CYCLES X 70 DIVISIONS

XXII

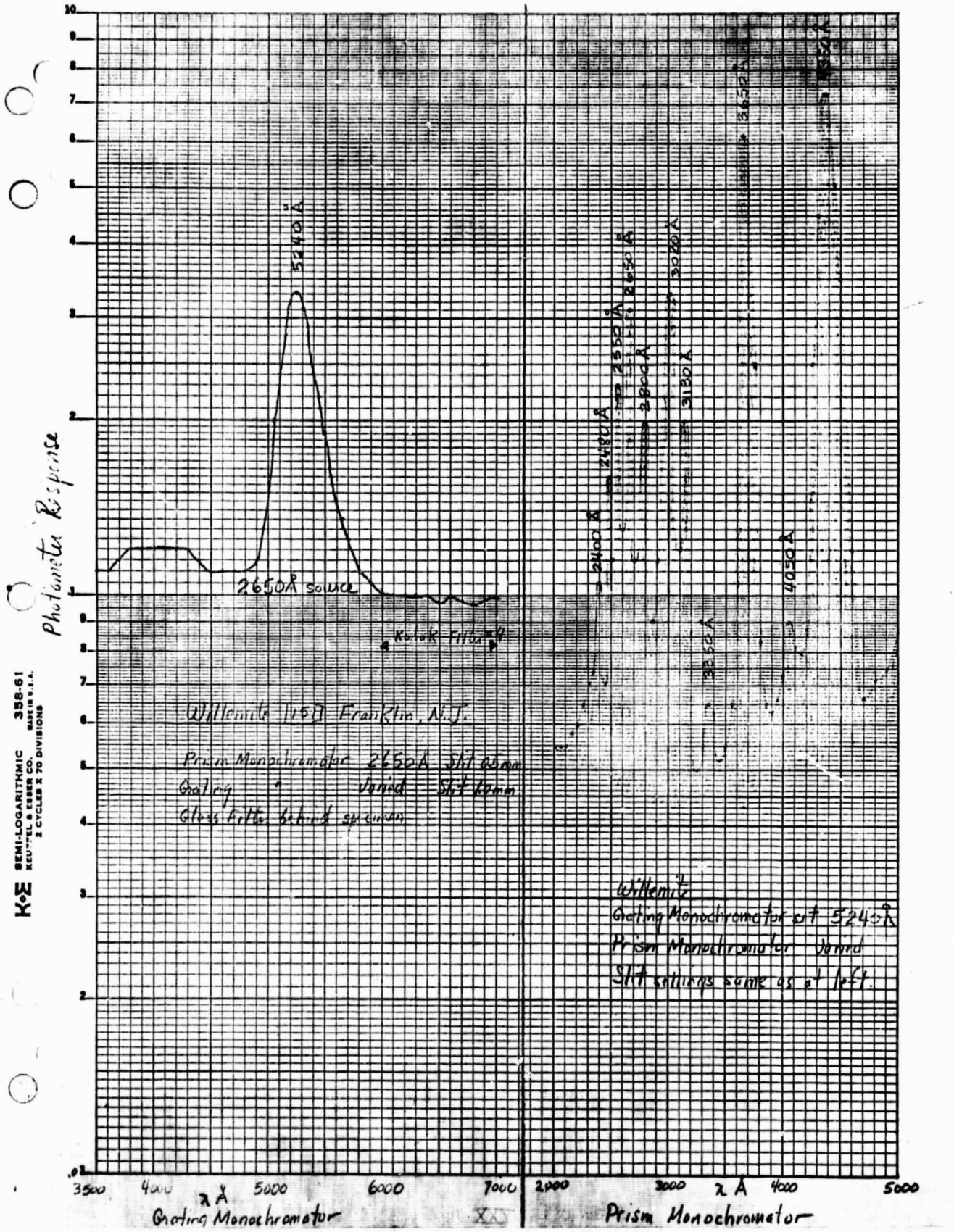

Calcite [212] Baker, West Virginia
4200 Å
3130 Å source
Quartz Prism Monochromator 4200 Å slit 10 mm
Grating Monochromator varied, slit 20 mm
Grating Monochromator 4200 Å
Quartz Prism Monochromator varied
slit openings same as at left
Photometer Response
SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS
10
9
8
7
6
5
4
3
2
1
3000
4000 (λ Å) 5000
6000
2000
3000 (λ Å) 4000
Grating Monochromator
Prism Monochromator

D.L. Daniels ~ Sept. 15, 1964

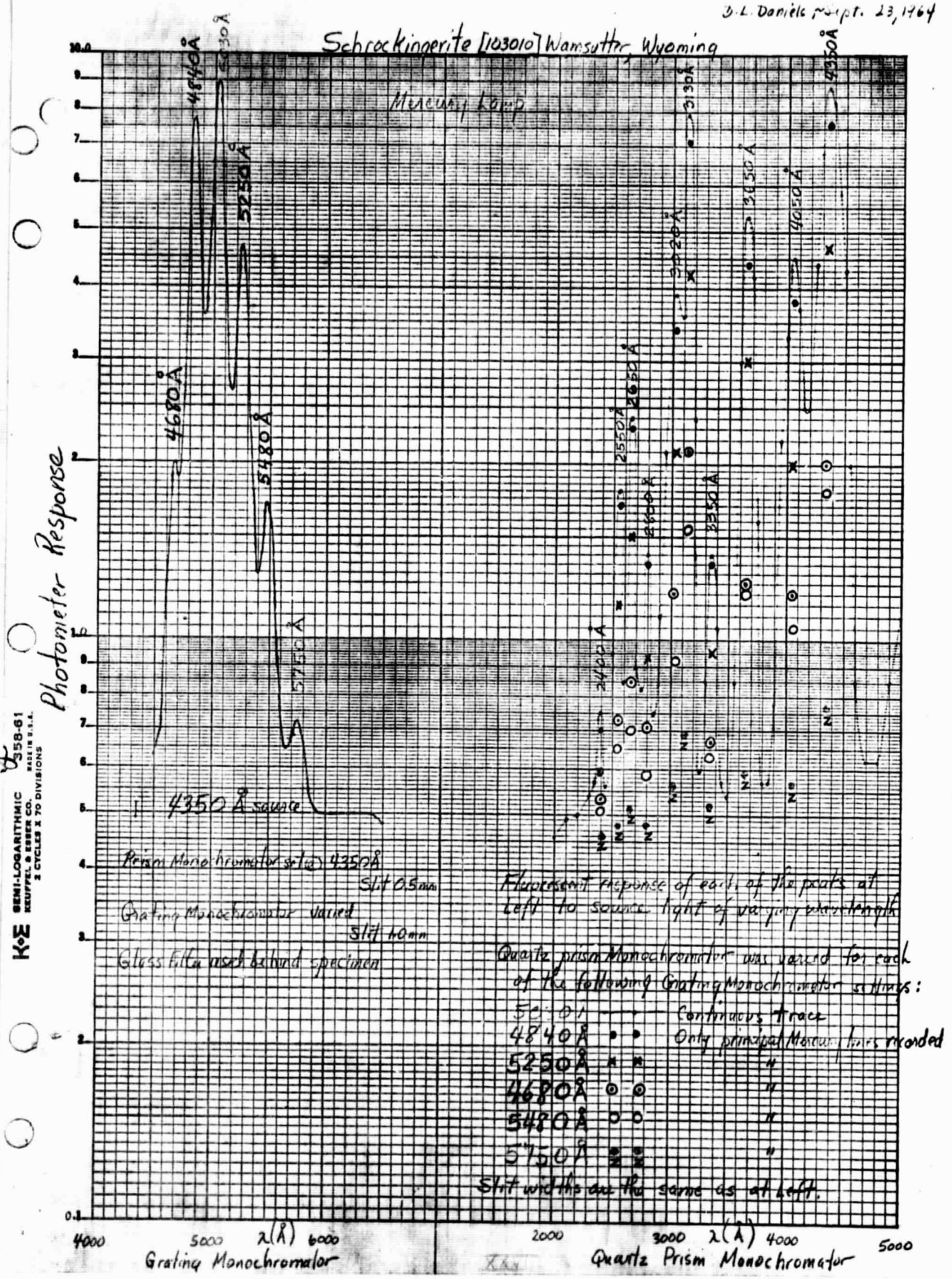


XXII

D.L. Daniels ~ Sept 17, 1964

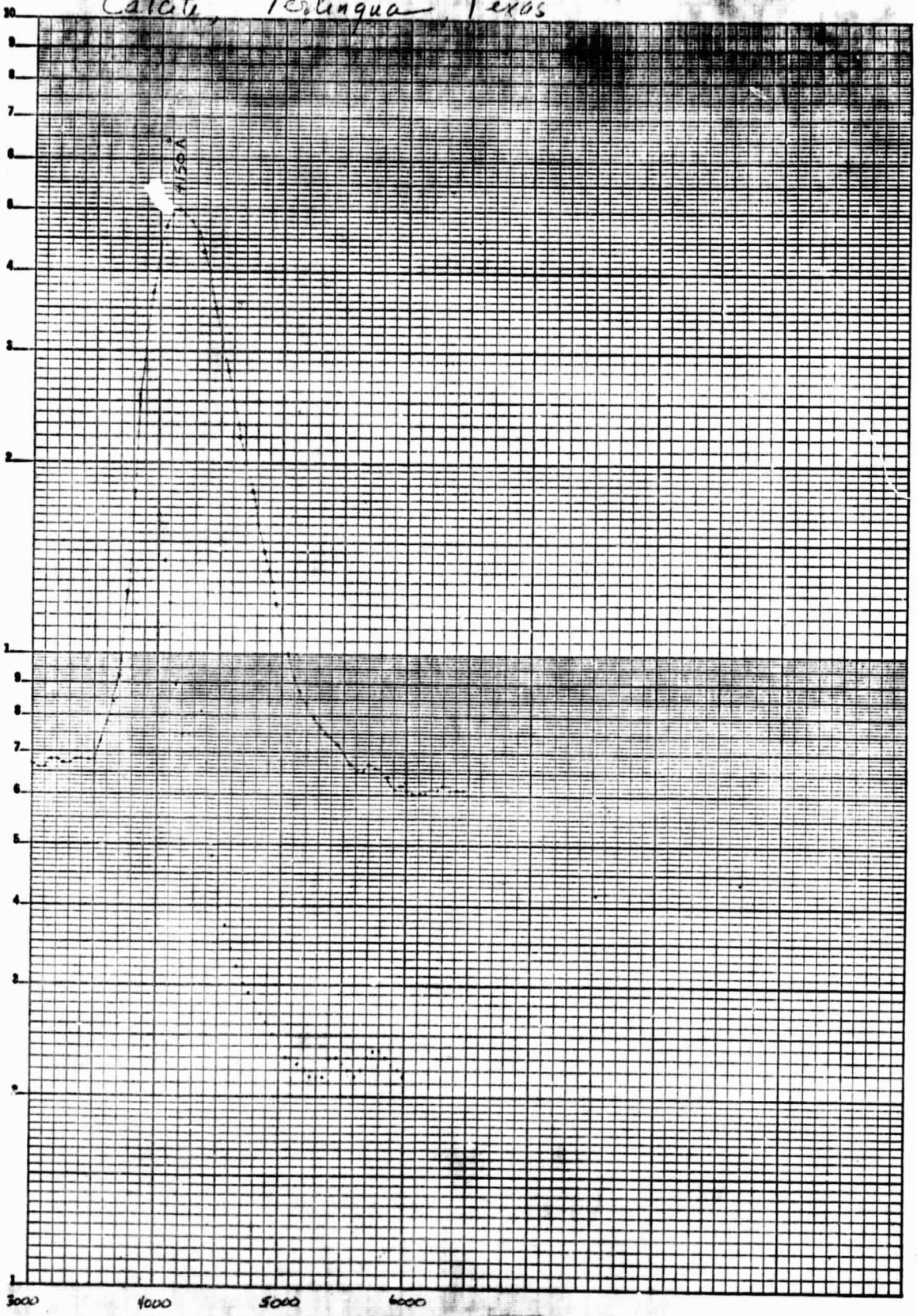


D. L. Daniels Sept. 23, 1964



D. L. Daniels 10-19-64

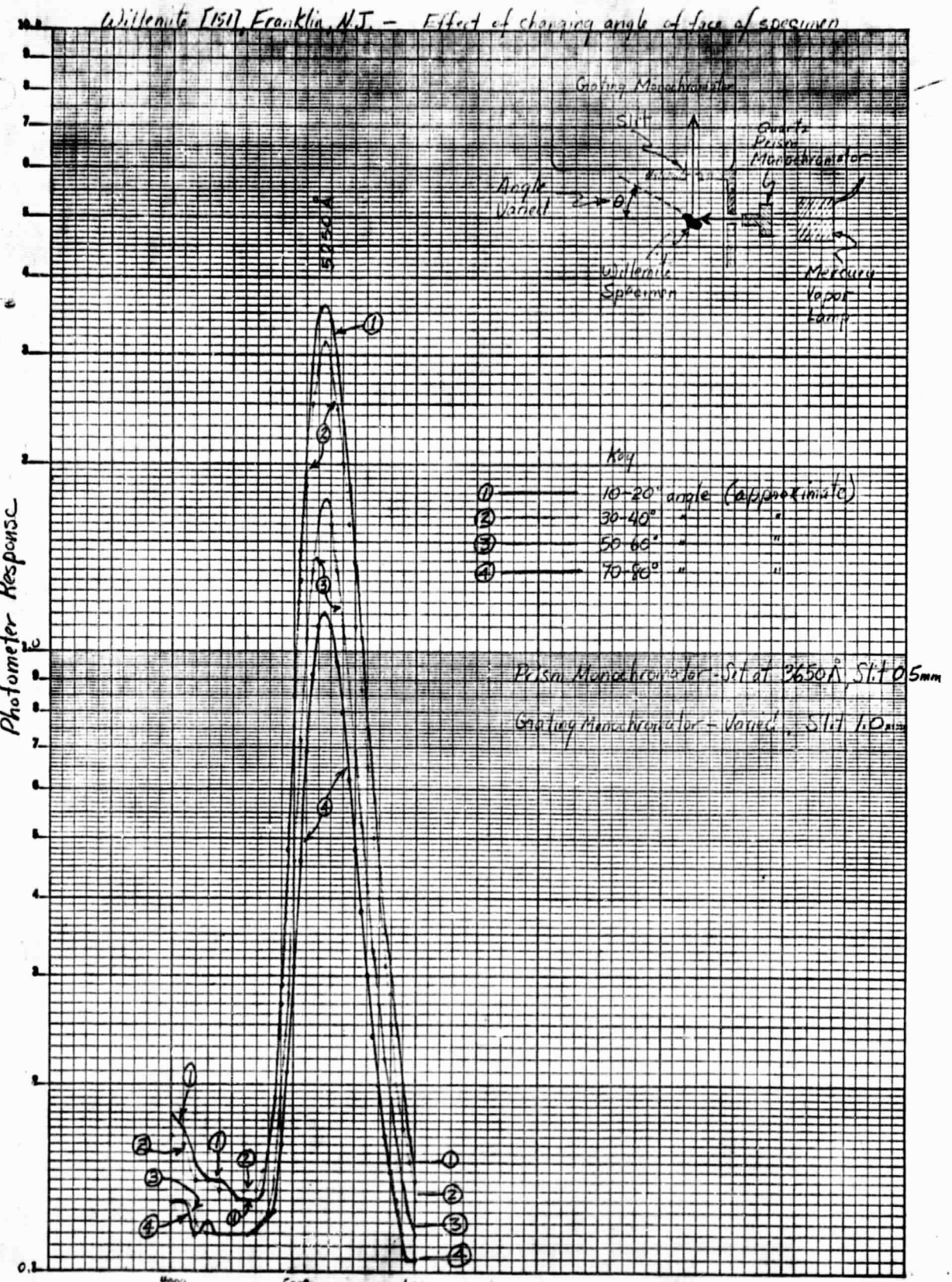
Calati, Terlingua Texas



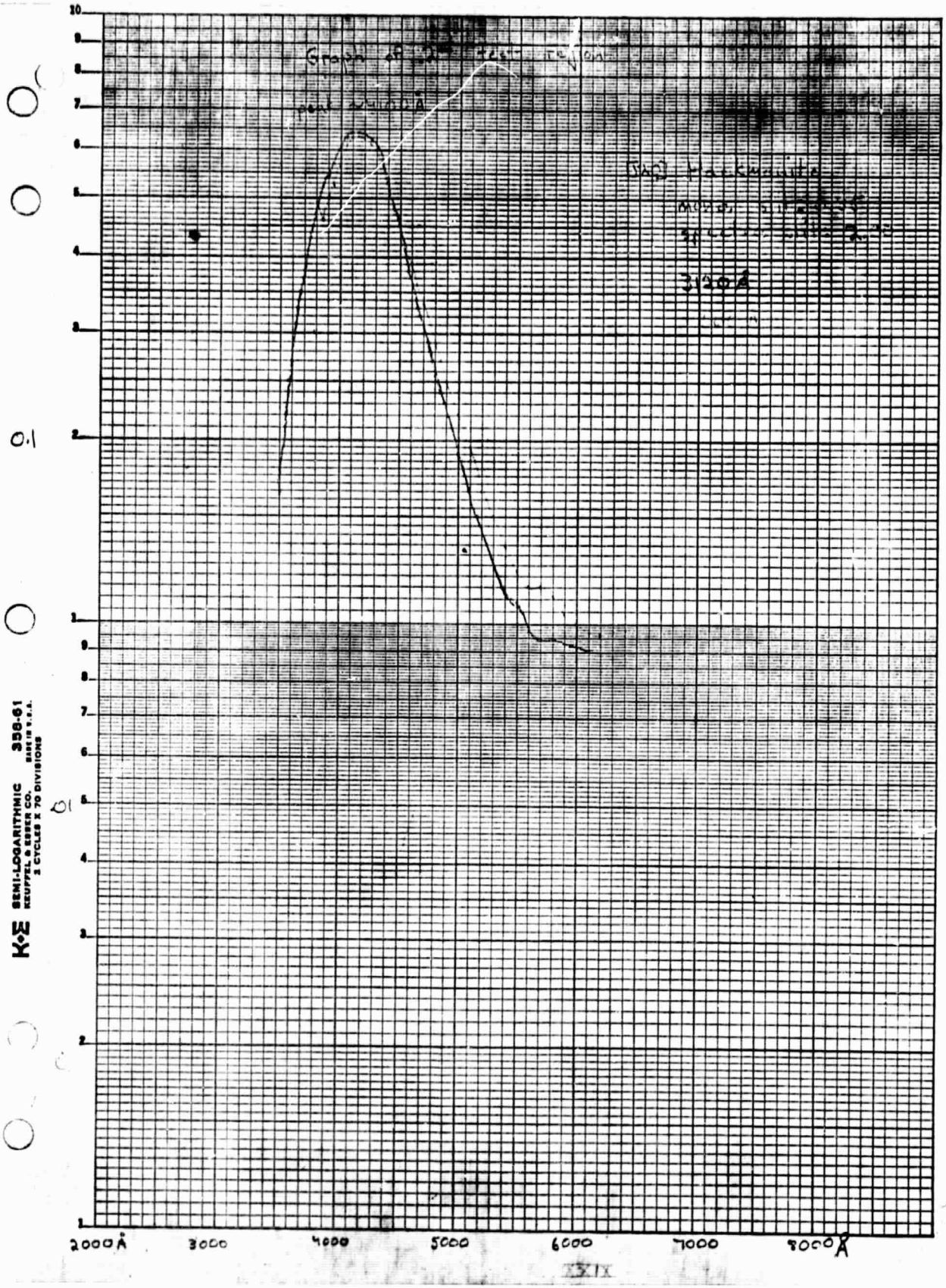
K+E SEMI-LOGARITHMIC 358-61 MADE IN U.S.A.
KEUFFEL & ESSER CO.
2 CYCLES X 70 DIVISIONS

D. L. Daniels Sept. 30, 1964

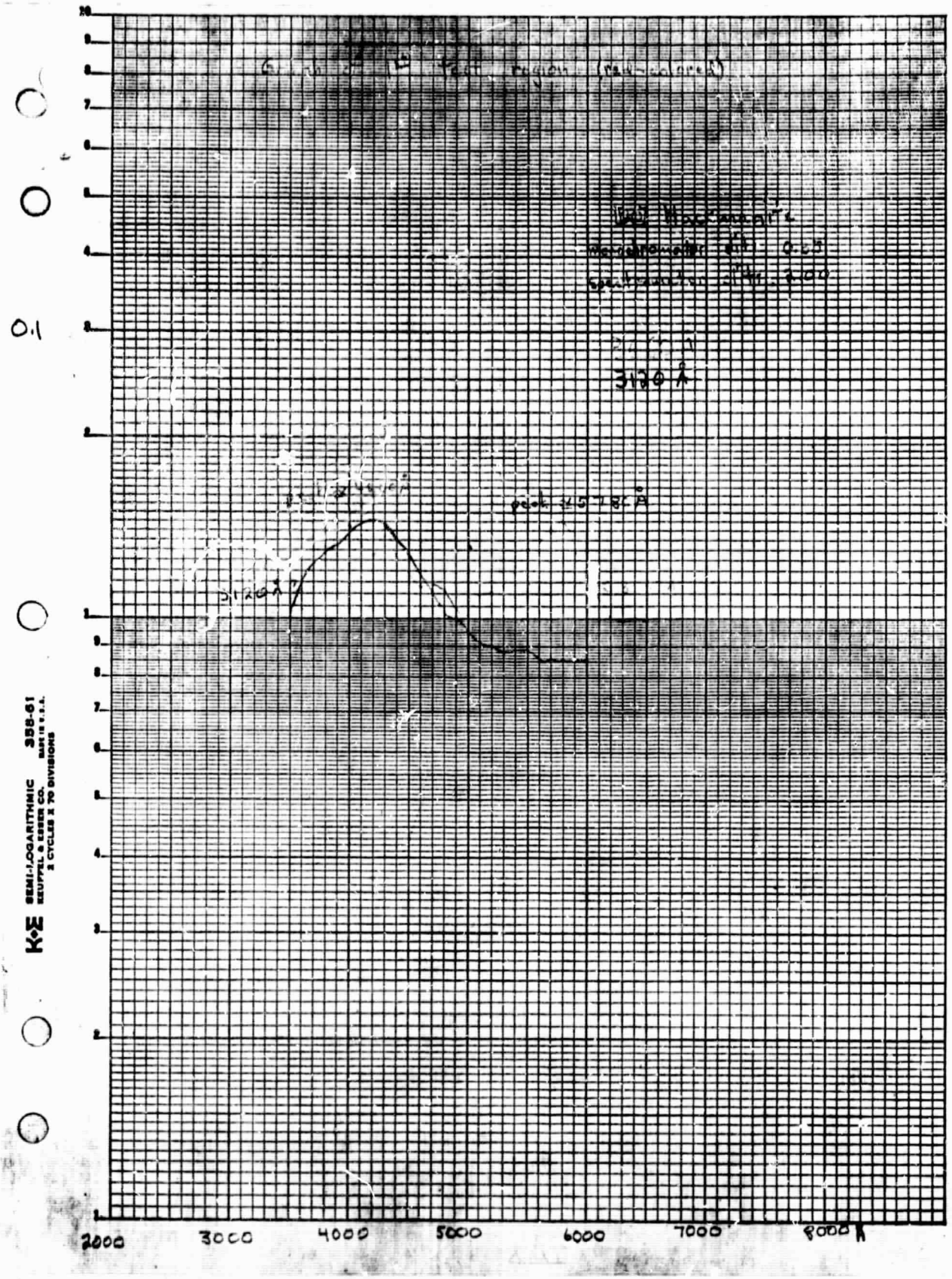
Willemite [151] Franklin, N.J. – Effect of changing angle of face of specimen

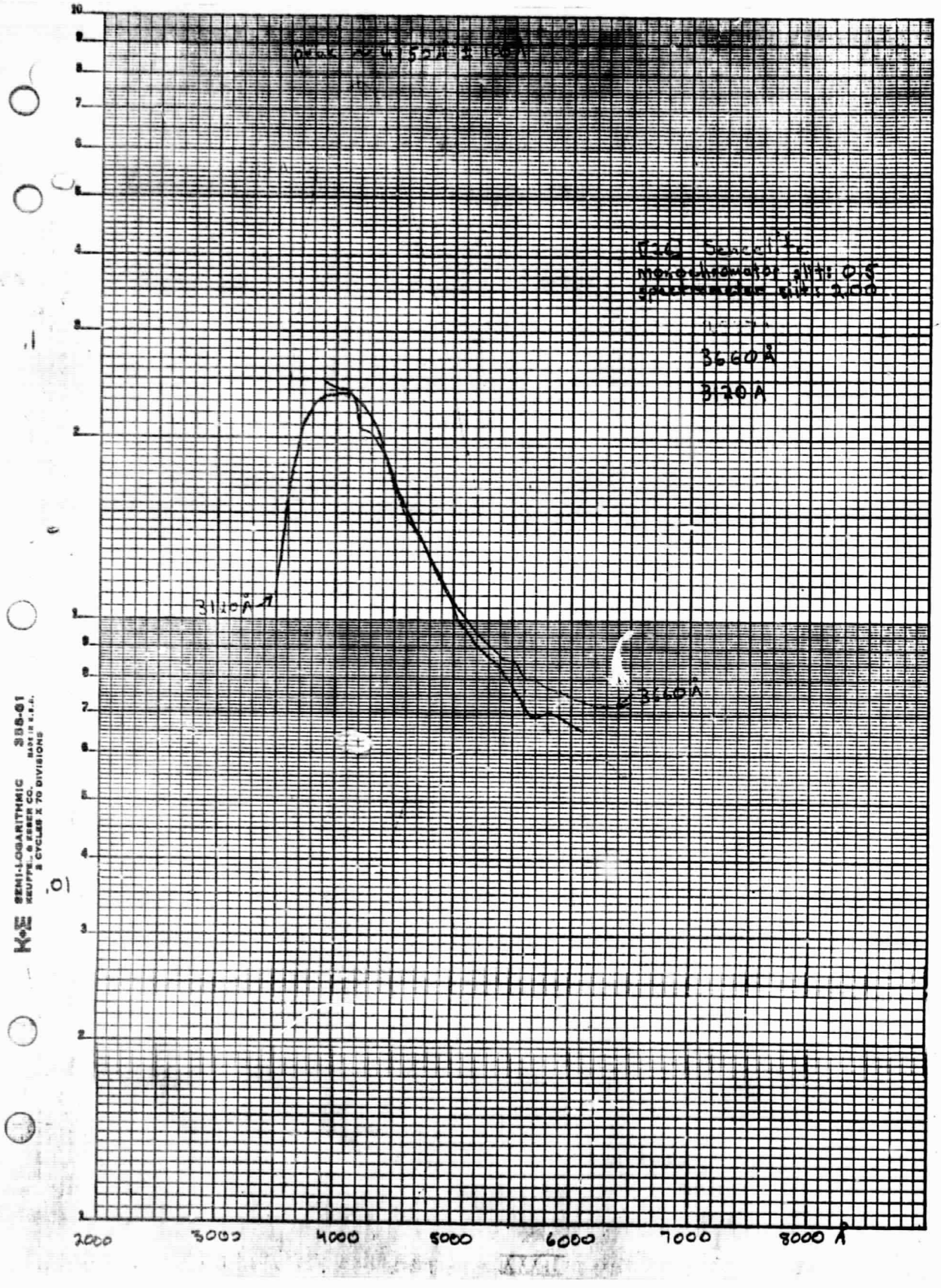


K&E 358-61 SEMI-LOGARITHMIC KEUFFEL & ESSER CO. MADE IN U.S.A. 2 CYCLES X 70 DIVISIONS

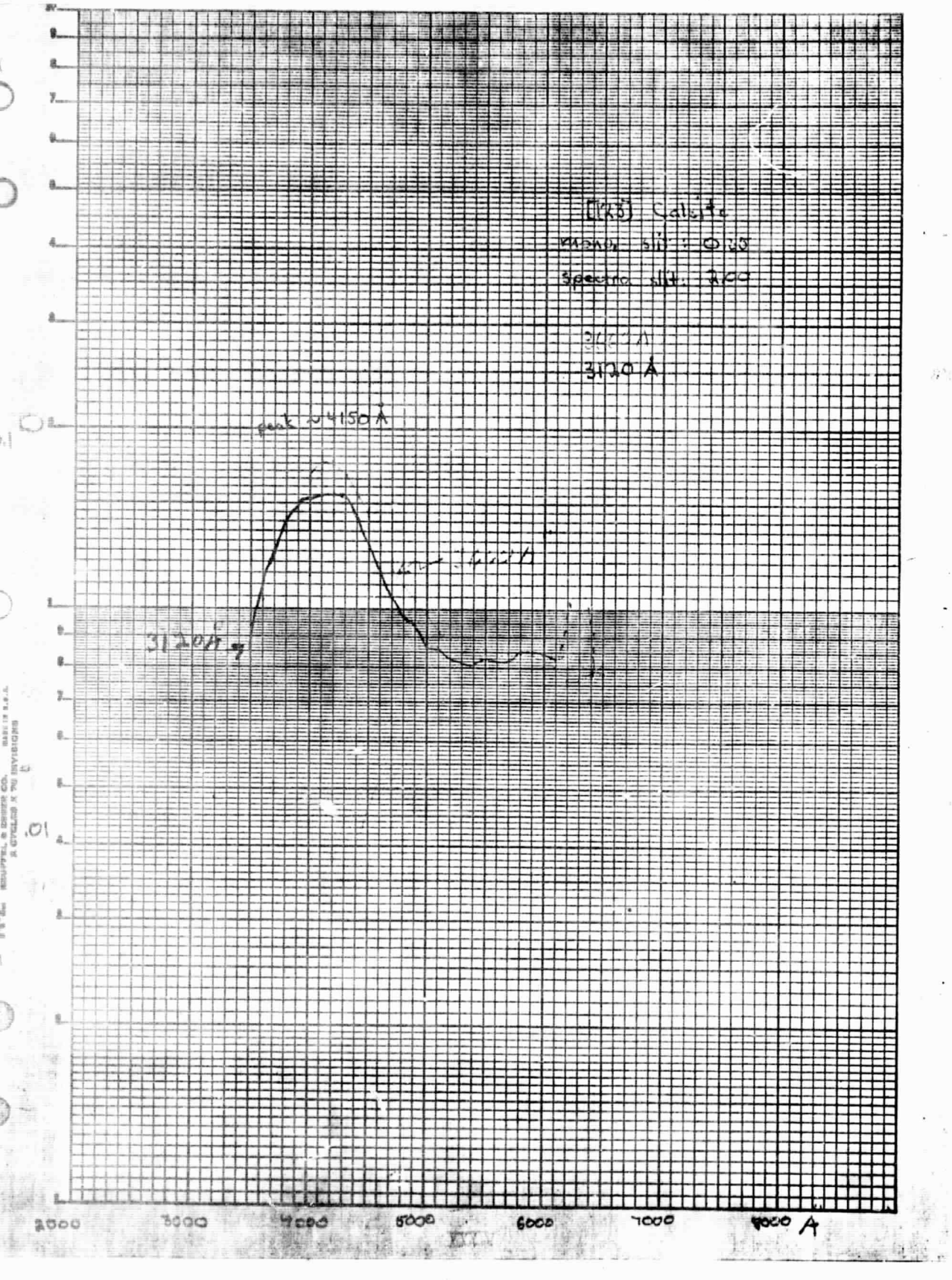

10
9
8
7
6
5
4
3
2
1
0.1
0.01
2000 Å
3000
4000
5000
6000
7000
8000 Å
3120 Å
K&E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS

K&E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
2000Å
3000
4000
5000
6000
7000
8000
3340Å
3537Å
.01


peak 4578 Å
3130 Å
2000
3000
4000
5000
6000
7000
8000
0.1
K&E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS

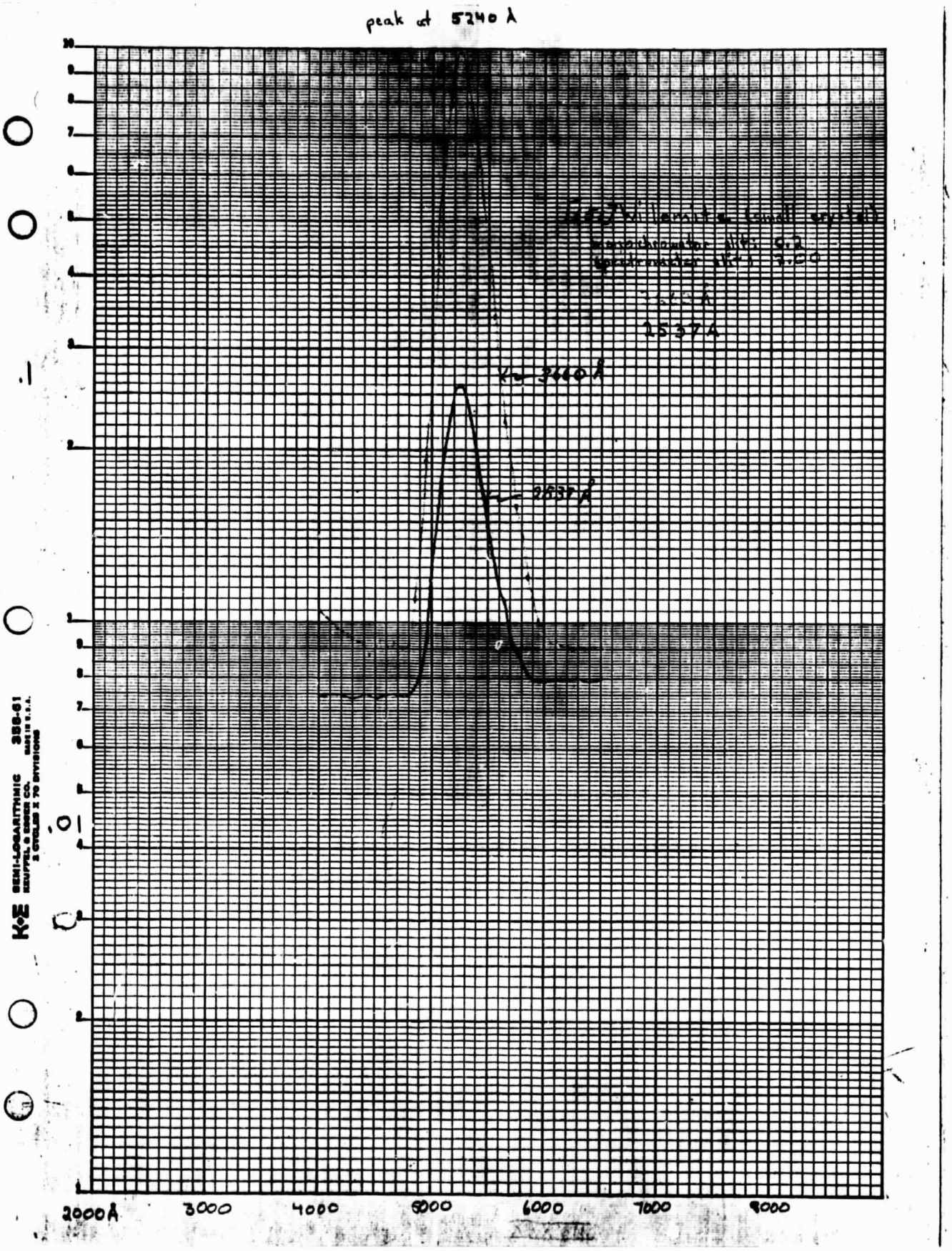

Peak at 4150Å ± 100Å
T-10 Sensitive monochromator slit: 0.5 spectrometer gain: 2,00
3660Å
3120Å
3110Å
3660Å
SEMI-LOGARITHMIC 358-81
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS
2000
3000
4000
5000
6000
7000
8000 Å

K&E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO.
2 CYCLES X 70 DIVISIONS
Range. Setting 2
1.0
3100Å
2000
3000
4000
5000
6000
7000
8000


(1x3) Calcite
3120 Å
peak ~4150 Å
3120 Å
2000
3000
4000
5000
6000
7000
8000 Å

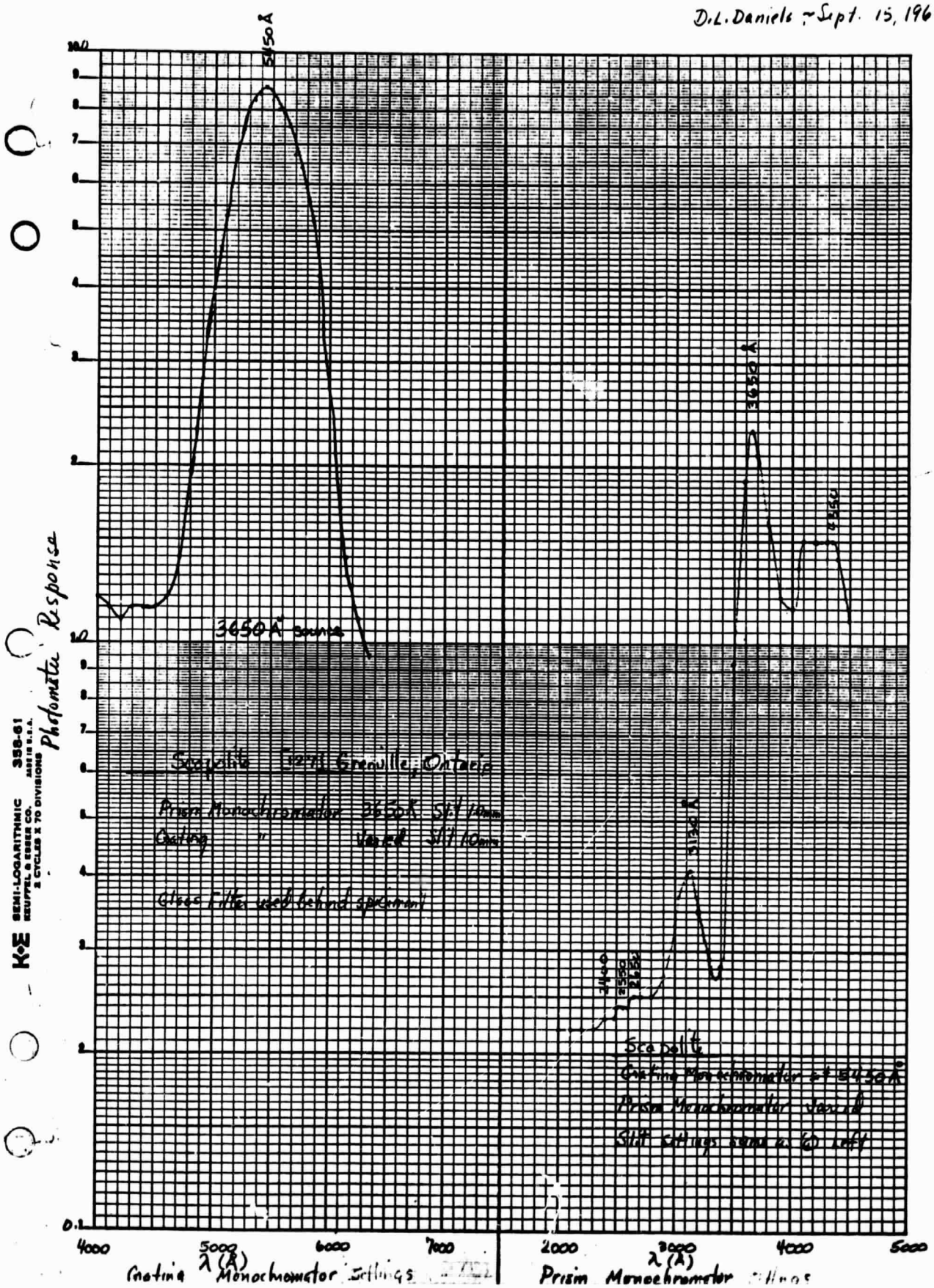
K&E
SEMI-LOGARITHMIC
KEUFFEL & ESSER CO.
2 CYCLES X 70 DIVISIONS
.01
3120
3120Å
2000Å
3000
4000
5000
6000
7000
8000

peak at 4210Å
peak at 3660Å
3120Å
2537Å
[86] Fluorene
Monochromator slit 0.5
Spectrometer slit:
3660 Å — 1.05
2537 Å — 2.00
3120 Å — 2.00
2537 Å
3120 Å
1.0
.1
.01
2000Å
3000
4000
5000
6000
7000
8000 Å
K&E SEMI-LOGARITHMIC 358-61
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS


peak at 5240 Å
Kα = 3440 Å
2537 Å
2000Å
3000
4000
5000
6000
7000
8000
1
.01

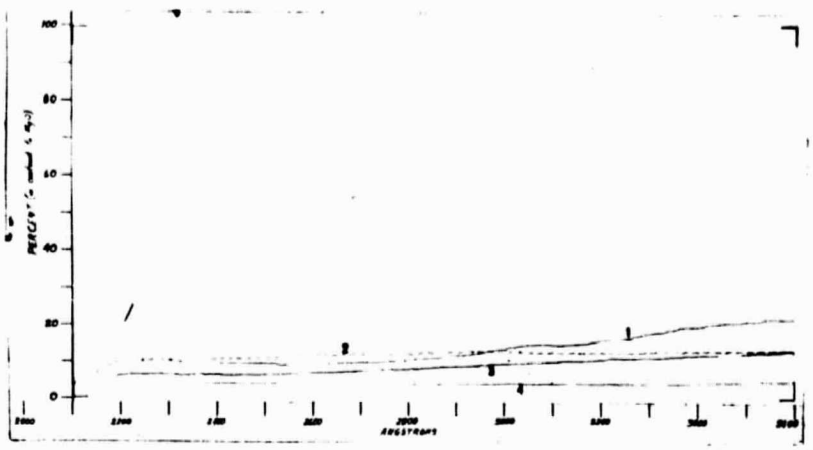
3120 Å
3120
0.1
0.01
2000 Å
3000
4000
5000
6000
7000
8000 Å
SEMI-LOGARITHMIC
KEUFFEL & ESSER CO.
2 CYCLES X 70 DIVISIONS

D.L. Daniels ~ Sept. 15, 1964

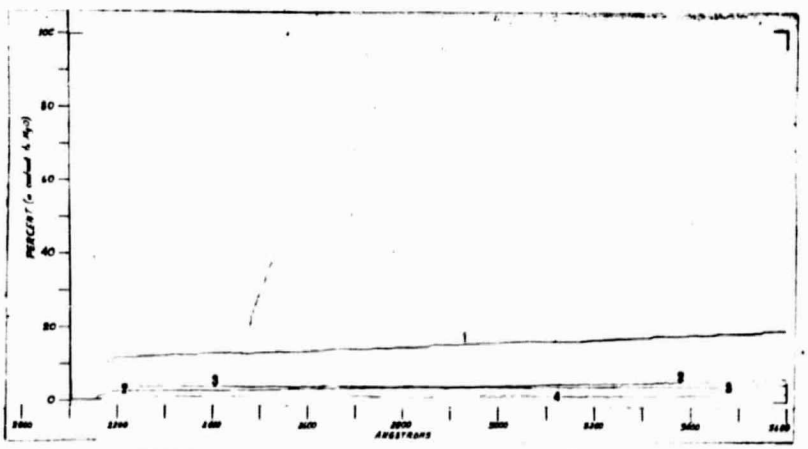


APPENDIX III

Appendix III-A

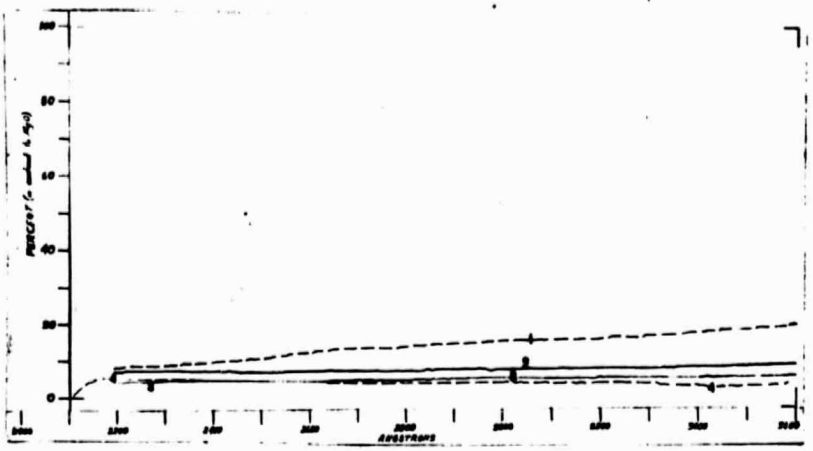


Reflection of ultraviolet light from: 1-Fluorite (Weardale, England); 2-Fluorite (Rosiclare, Illinois); 3-Fluorite (South Park, Colorado); 4- Fluorite (Rosiclare, Illinois).

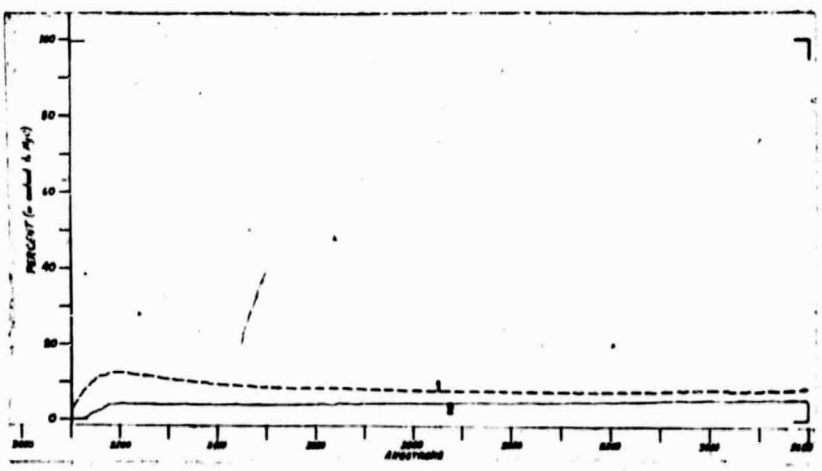


Reflection of ultraviolet light from: 1-Gypsum (Grand Rapids, Michigan); 2-Corundum (Transvaal, Africa); 3- Topaz (Brewer Mine, South Carolina); 4- Cassiterite (Bolivia).

Appendix III-A

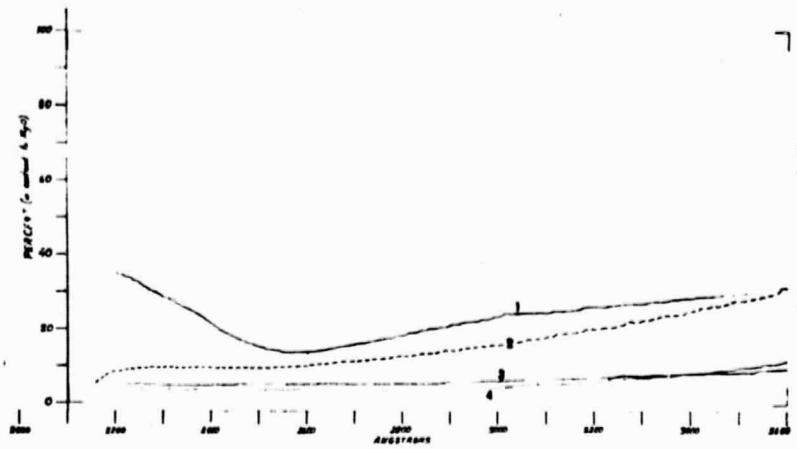


Reflection of ultraviolet light from: A-1 Dolomite, %$MgCO_3$ 42.0(unweathered) (Wise County, Virginia); A-2-Dolomite, %$MgCO_3$ 42.0(weathered) (Wise County, Virginia); B-3-Limestone, %$MgCO_3$ 1.9 (weathered) (Wise County, Virginia); B-4 Limestone, %$MgCO_3$ 1.9 (unweathered) (Wise County, Virginia).

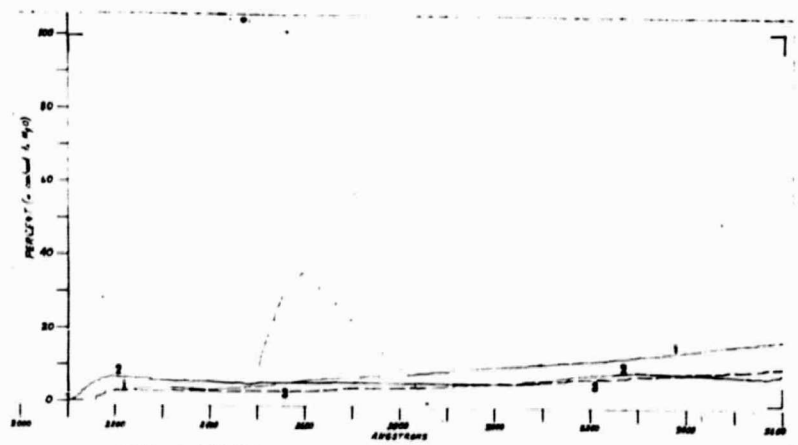


Reflection of ultraviolet light from: 1-Sphalerite (Ottawa County, Oklahoma); 2-Calcite (Shenandoah Cave, Virginia).

Appendix III-A

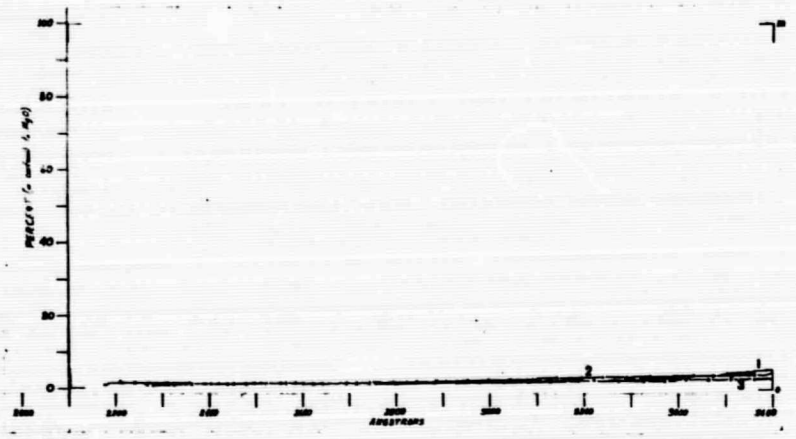


Reflection of ultraviolet light from: 1- Amazon Stone (Amelia Courthouse, Virginia); 2- Zinnwaldite (Amelia Courthouse, Virginia); 3-Beryl & Quartz (Amelia Courthouse, Virginia); 4-Clevelandite feldspar (Amelia Courthouse, Virginia).

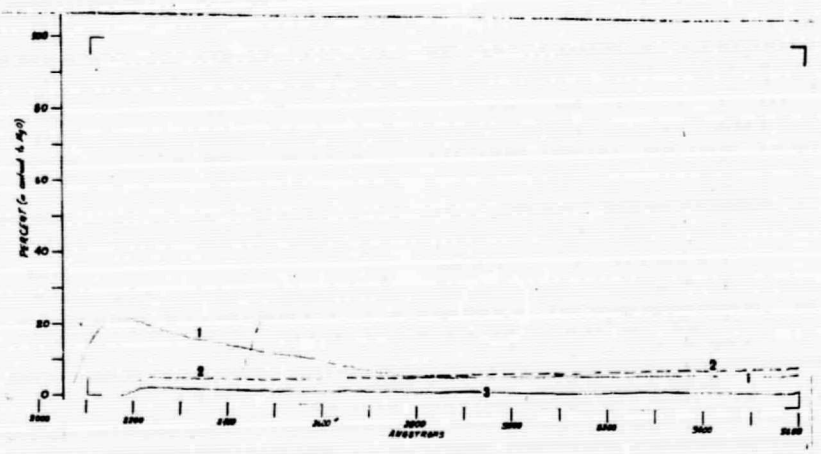


Reflection of ultraviolet light from: 1-White paint(flo-paque); 2- Willemite (Franklin, New Jersey); 3- Calcium Larsenite (Franklin, New Jersey).

Appendix III-A

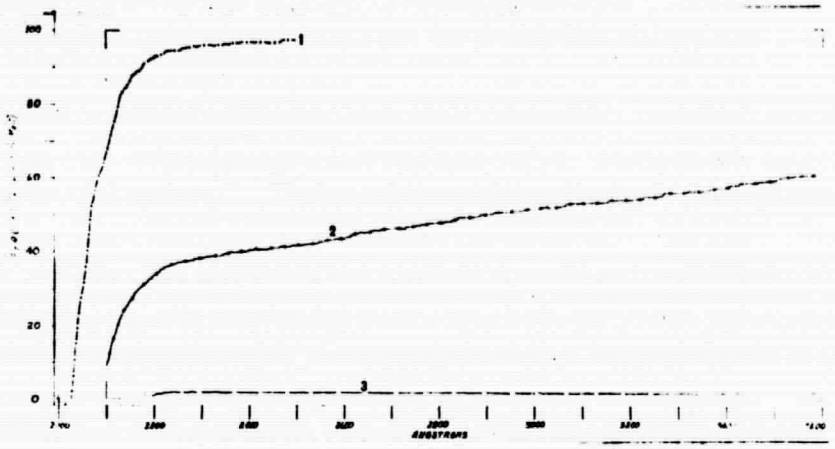


Reflection of ultraviolet light from: 1-White birch-no bark (Bethesda, Maryland); 2-White birch-with bark (Bethesda, Maryland); 3-Swamp Oak-with bark (Bethesda, Maryland).

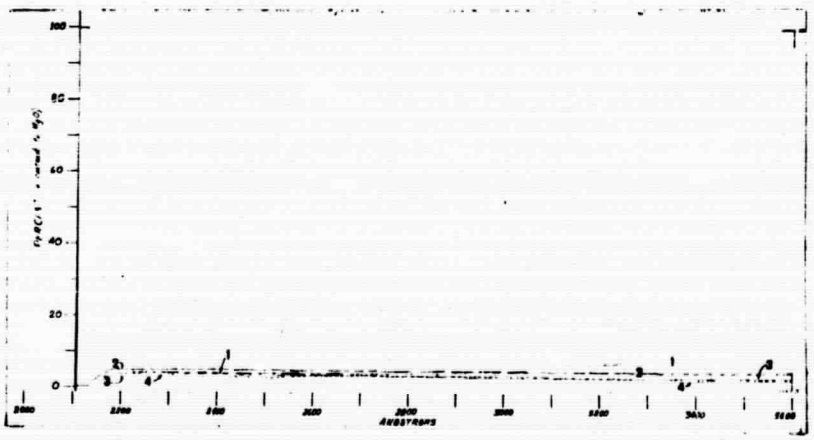


Reflection of ultraviolet light from: 1-Scheelite (Timmins, Ontario); 2-Quartzite (unweathered); 3-Quartzite (weathered).

Appendix III-A



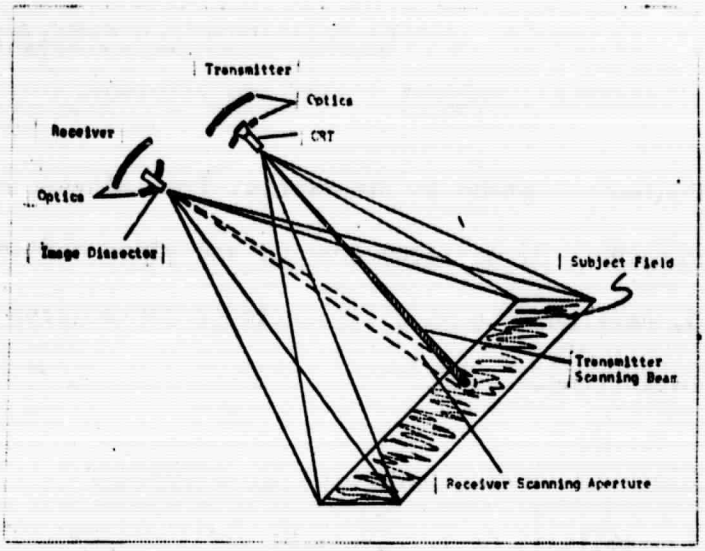
Reflection of ultraviolet light from: 1-Magnesium oxide; 2-Aluminum foil; 3-Monozite.



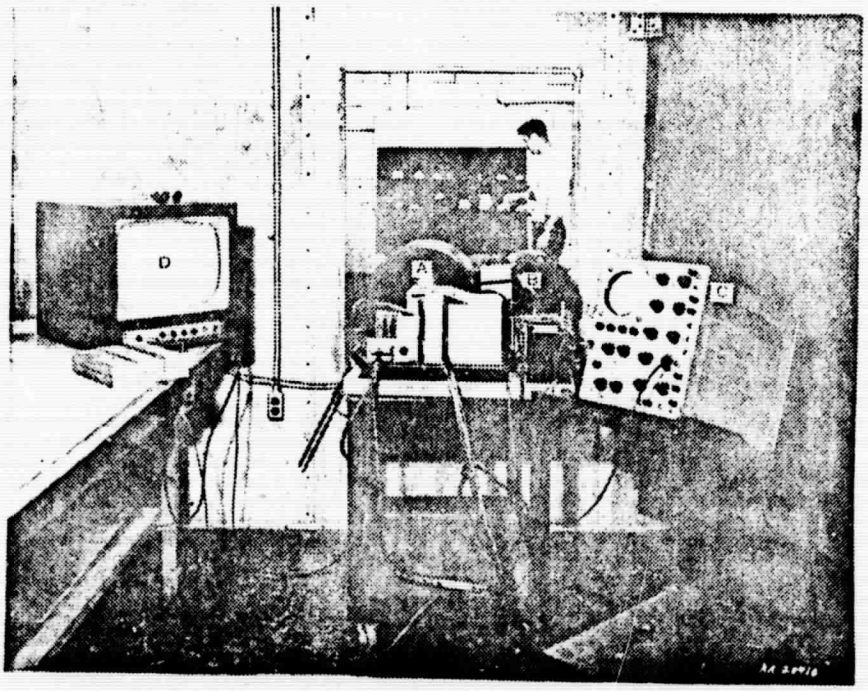
Reflection of ultraviolet light from: 1-Kyanite (Baker Mtn., Virginia); 2-Halite (Wieliczka, Poland); 3-Tektite (java); 4-Tektite (Java).

ILLUSTRATIONS

ILLUSTRATIONS

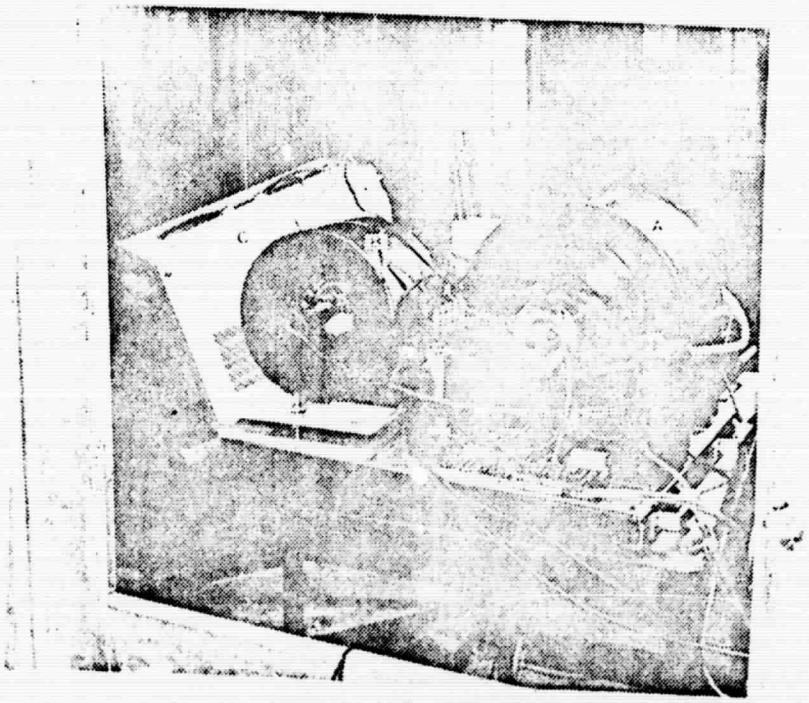

Transmitter
Optics
CRT
Receiver
Optics
Image Dissector
Subject Field
Transmitter Scanning Beam
Receiver Scanning Aperture

I-1


D
A
B
C

I-2

I-3



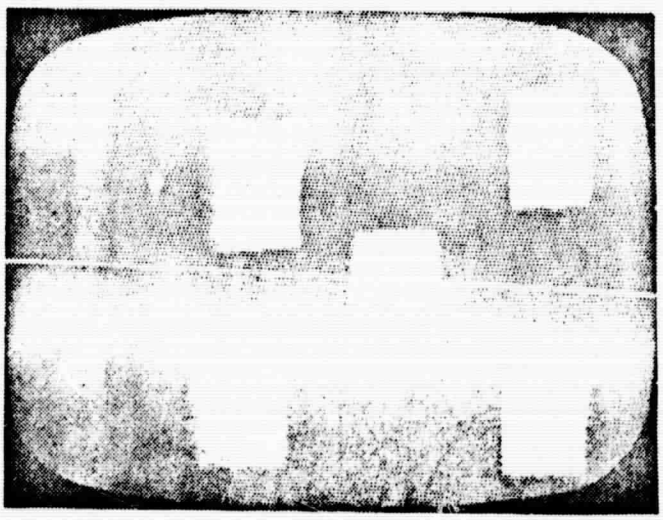
I-4

Figure I-4. Close-up showing installation of the P-16 cathode ray tube and the CBS S-13 image dissector tube in the transmitter and receiver, respectively. Transmitter, A; receiver, B; and oscilloscope, C.

I-5. Close-up showing video monitor imaging luminescing minerals shown on rack in figure I-2.

I-6. Video monitor showing relative image brightness of identical luminescent panels. Images are brightest near the center of the panel layout.

I-5



I-6

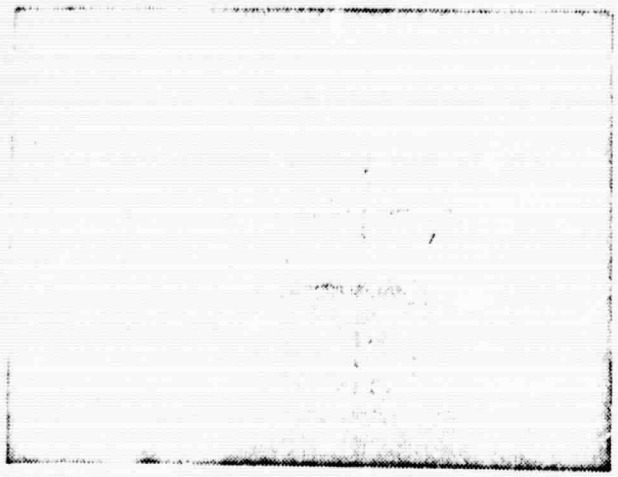
Figure I-7. Video monitor images of scapolite (left) and hackmanite which were placed one inch apart 15 feet from the transmitter-receiver. Minerals are hand specimens, two to three inches wide.

I-8. A-scope at 0.5 v/cm. Peaks represent scapolite (left) and hackmanite under same subject conditions as figure I-7.

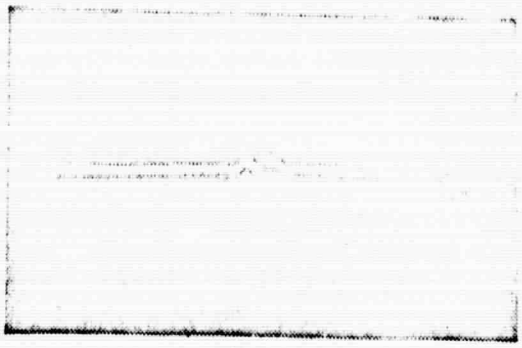
I-9. Video monitor images of scapolite (left) and hackmanite which were placed one inch apart 20 feet from the transmitter-receiver.

I-10. Video monitor images of scapolite (left) and hackmanite which were placed one inch apart 25 feet from the transmitter-receiver.

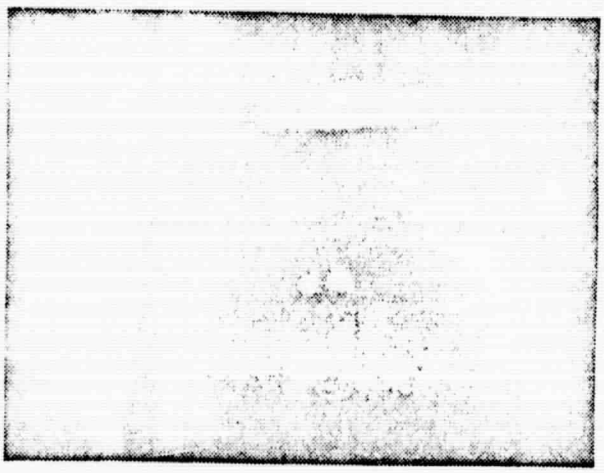
I-11. Video monitor images of scapolite (left) and hackmanite which were placed one-half inch apart 25 feet from the transmitter- receiver.



I-7

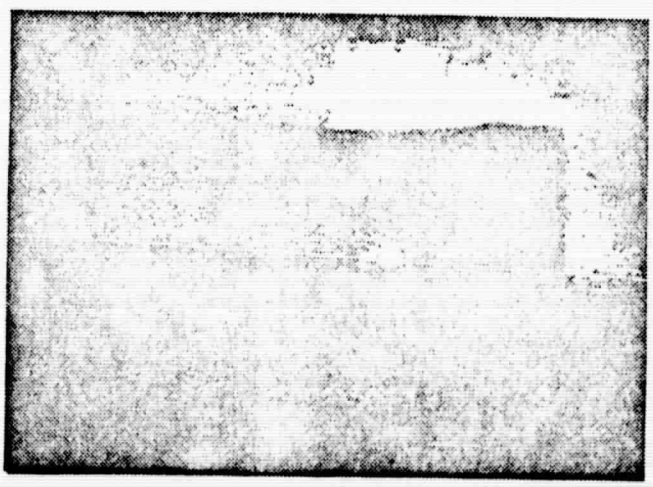


I-8



I-9

I-10



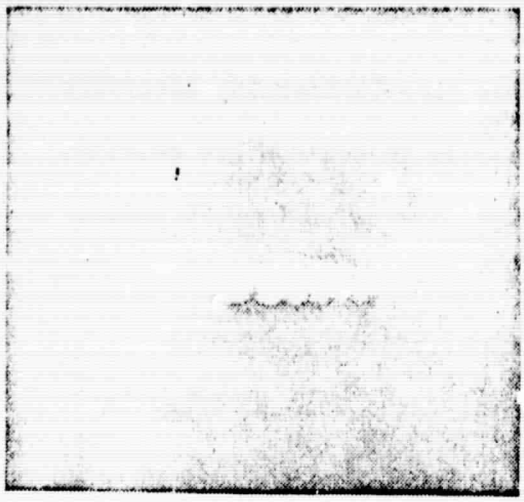
I-11

Figure I-12. Video monitor images of target made of seven strips of luminescent bunting. Strip on left is two inches wide; strip seen faintly on right is one thirty-second inch wide. Subject distance is 15 feet.

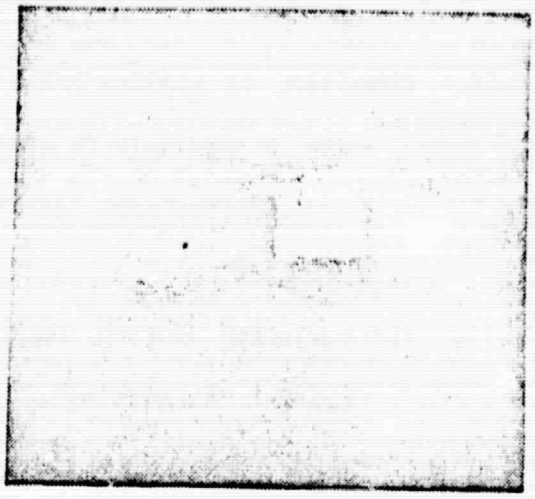
I-13. Video monitor showing luminescent panel strongly imaged from "face-on" orientation.

I-14. Video monitor showing luminescent panel weakly imaged after being turned from a "face-on" orientation. Because receiver was not filtered, panel's image in figures I-13 and I-14 is due to reflected UV light.

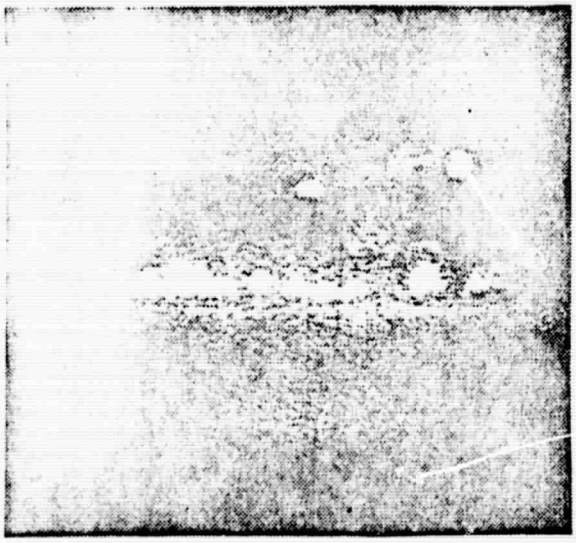
I-15. Video monitor showing luminescent panel strongly imaged after filtering the receiver with a Corning 3-72 and increasing the gain. An equally strong image was made when the panel was tilted, indicating a near lambertian distribution of emitted energy.



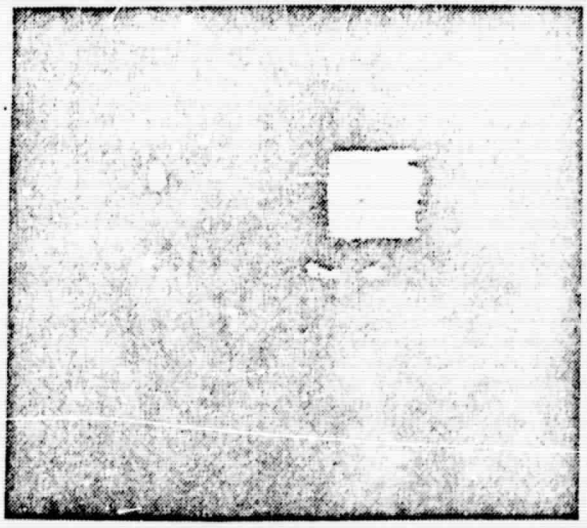
I-12



I-13



I-14

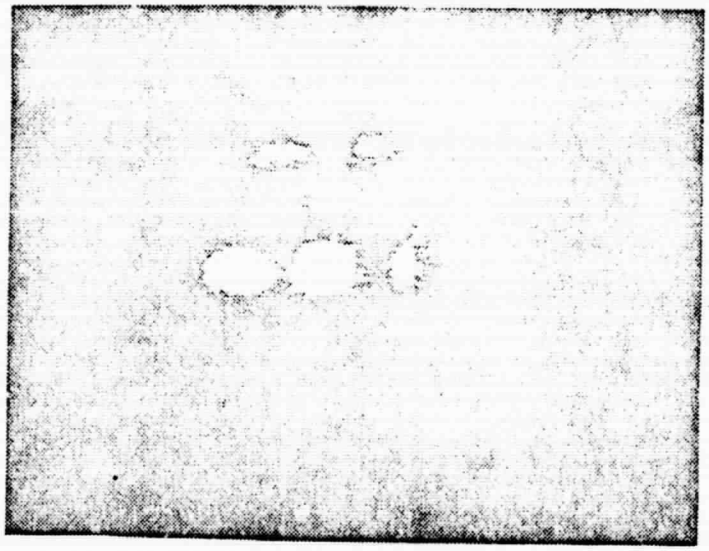


I-15

Figure I-16. Video monitor showing images of the five luminescing specimens shown in Appendix D. Both minerals in top row are calcite; in the bottom row, left to right, are scapolite, fluorite, and calcite.

I-17. Video monitor showing images of same specimens shown in figure I-16 immediately after they have been immersed in water.

I-16



I-17

Figure I-18. Video monitor images of two pieces of calcite at ambient temperature of 15.5°C. Both pieces were broken from the same specimen and are oriented with common surfaces facing the transmitter-receiver.

I-19. A-scope 100 mv/cm. Same as figure I-18.

I-20. Video monitor. Same conditions as figure I-18 except that the specimen on the right has been heated to 80°C.

I-21. A-scope at 100 mv/cm. Same as figure I-20.

I-22. Video monitor. Same conditions as figures I-18 and I-20 except that the specimen on the right has cooled to 40°C.

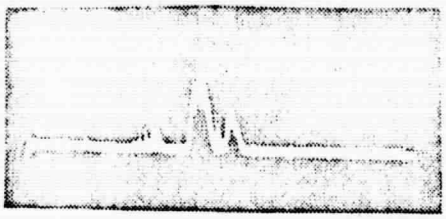
I-23. A-scope at 100 mv/cm. Same as figure I-22.

I-24. Video monitor. Same as figure I-18 except that specimen on right has been cooled to -30°C.

I-25. A-scope at 100 mv/cm. Same as figure 24. Note that here A-scope peaks for both specimens are nearly equal.

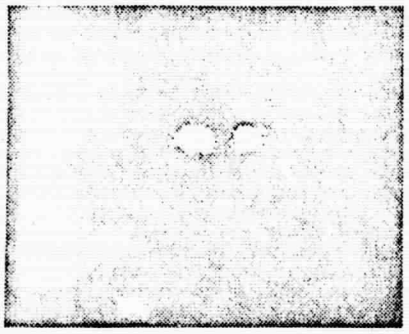
I-18

I-20

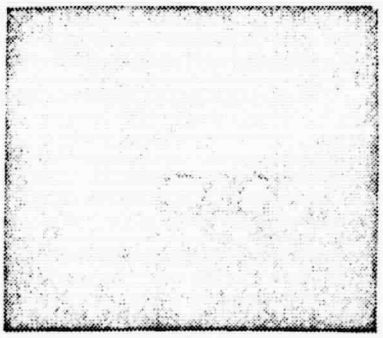


I-19

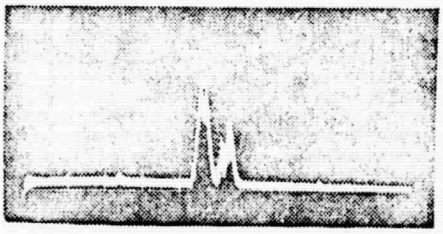
I-21



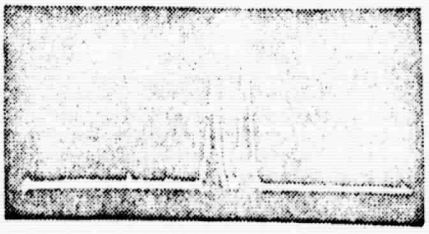
I-22



I-24



I-23



I-25

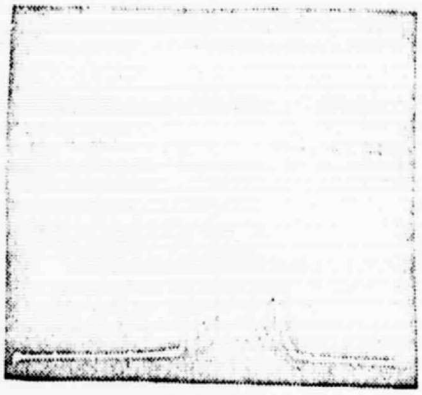
Figure I-26. Video monitor images of nine Group I minerals used in preliminary study of the effect of selected receiver filters. Layout of minerals is shown in Appendix E. Top row, left to right: scheelite, quartz cobble, willemite, willemite and franklinite, and calcium larsenite. In the bottom row, left to right: quartz, calcite, scapolite, and fluorite. Receiver is not filtered in this illustration.

I-27. A-scope. Same as figure I-26. Top line at 50 mv/cm; bottom line at 100 mv/cm.

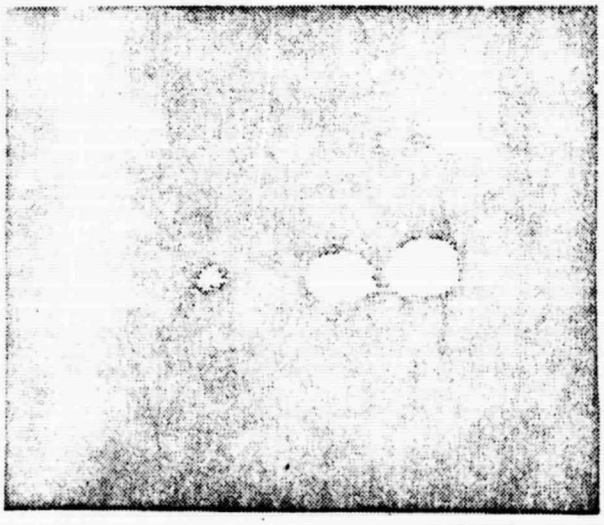
I-28. Video monitor. Same as figure I-26 except that a Corning 3-73 filter has been introduced on the receiver.

I-29. A-scope. Same as figure I-28. Top line at 50 mv/cm; bottom line at 200 mv/cm.

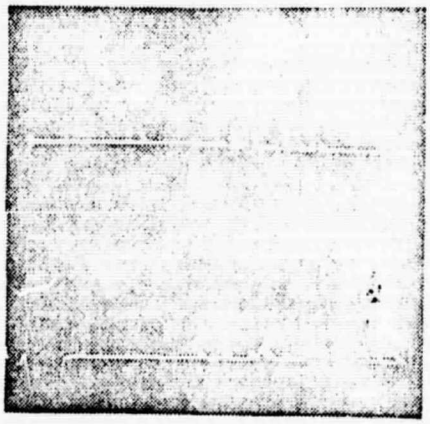
I-26



I-27



I-28



I-29

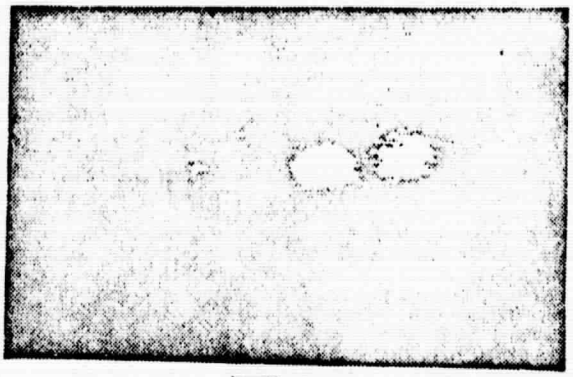
Figure I-30. Video monitor. Same as figure I-26 except that a Corning 3-72 filter has been introduced on the receiver.

I-31. Video monitor. Same as figure I-26 except that a Kodak ~~K-4~~ filter has been introduced on the receiver.

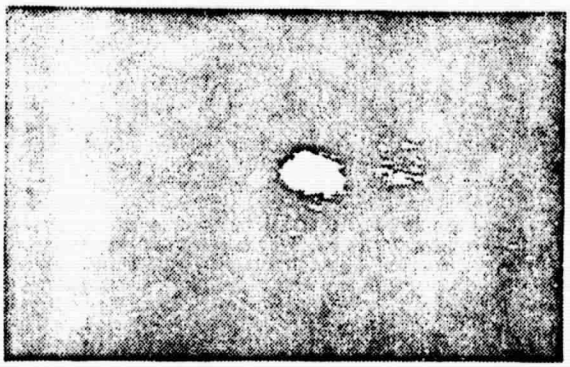
I-32. A-scope. Same as figure I-31. Bottom line at 100 mv/cm.

I-33. Video monitor. Same as figure 26 except that a Kodak 8 (K-2) filter has been installed in the receiver.

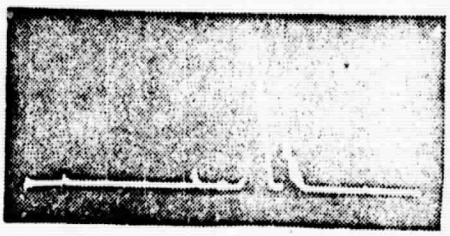
I-34. A-scope. Same as figure I-33. Bottom line only at 100 mv/cm.



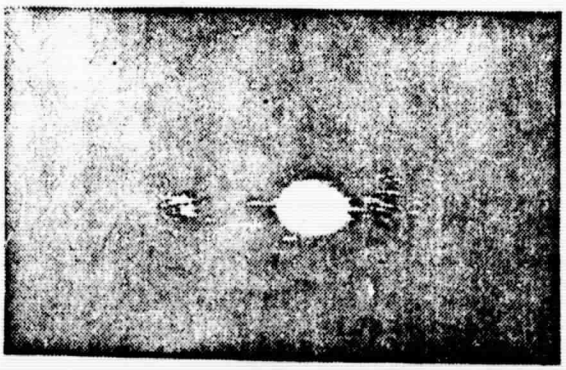
I-30



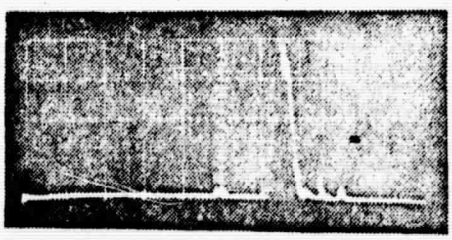
I-31



I-32



I-33



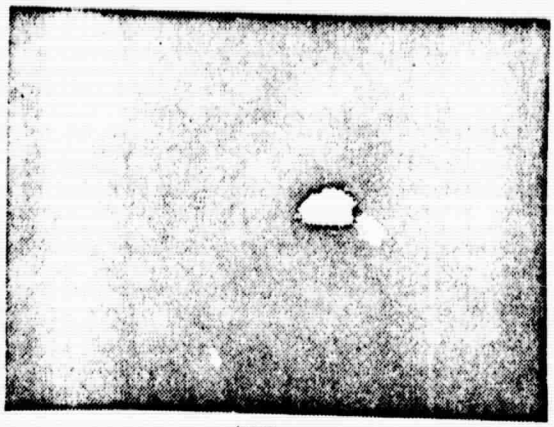
I-34

Figure I-35. Video monitor. Same as figure I-26 except that a ~~Corning~~ K.J.K 15g has been installed on the receiver.

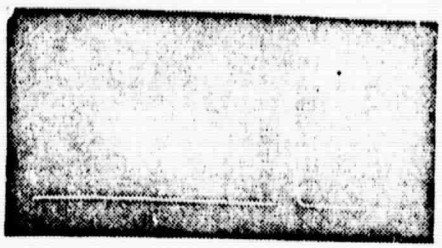
I-36. A-scope. Same as figure 35. Bottom line at 100 mv/cm.

I-37. Video monitor. Same as figure I-26 except that a ~~Corning~~ K.J.K 16 filter has been installed on the receiver.

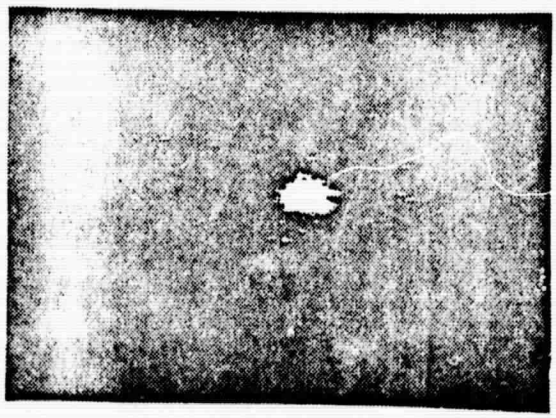
I-38. A-scope. Same as figure I-37. Bottom line at 100 mv/cm.



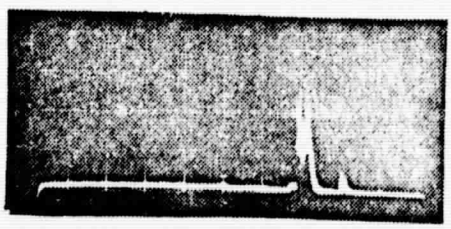
I-35



I-36



I-37



I-38

Figure I-39. Video monitor images of seven Group II specimens used in preliminary study of the effect of selected receiver filters. Layout of specimens is shown in Appendix F. In the top row, left to right: magnesium oxide, willemite, fluorite, and calcite. In the bottom row, left to right: calcite veins in limestone, phosphate, and colemanite. Receiver is not filtered in this illustration.

I-40. A-scope. Same as figure I-39. 20 mv/cm; gain used here was arbitrarily selected as reference standard in figures I-41 to I-42.

I-41. Video monitor. Same as figure I-39 except that a Corning 3-73 filter has been introduced on the receiver.

I-42. A-scope. Same as figure I-41. 50 mv/cm.

I-43. Video monitor. Same as figure I-39 except that a Corning 3-72 filter has been introduced on the receiver.

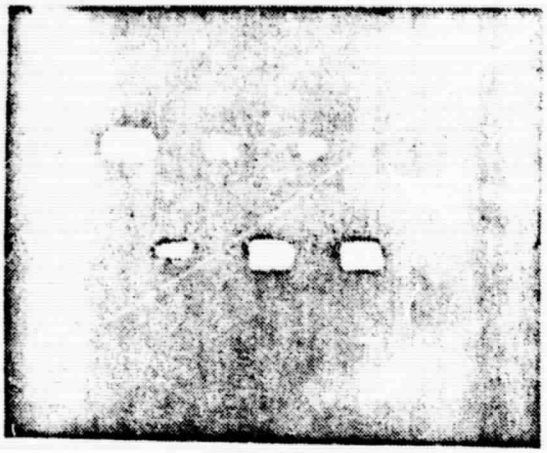
I-44. A-scope. Same as figure I-43. 50 mv/cm.

Figure I-45. Video monitor. Same as figure I-39 except that a Kodak ~~#4~~ 4 filter has been introduced on the receiver.

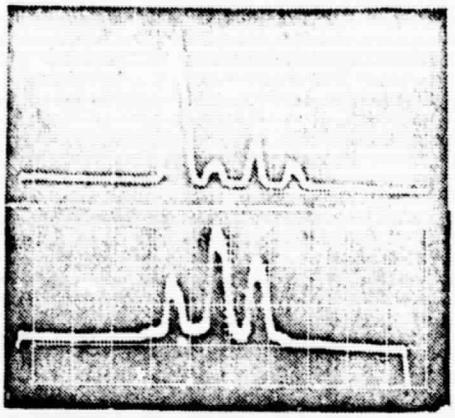
I-46. A-scope. Same as figure I-45. 20 mv/cm.

I-47. Video monitor. Same as figure I-39 except that a Kodak 8 (K-2) has been installed on the receiver.

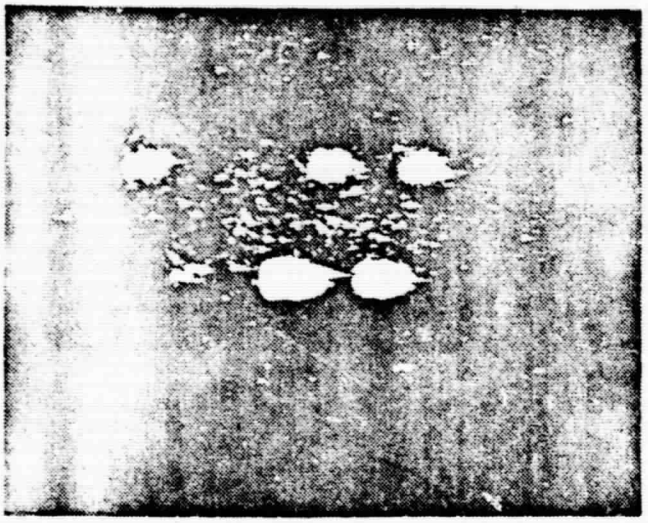
I-48. A-scope. Same as figure I-47. 20 mv/cm.



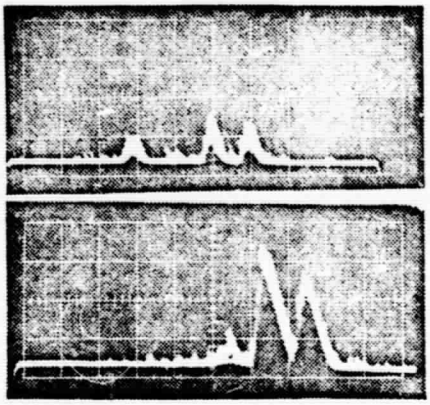
I-39



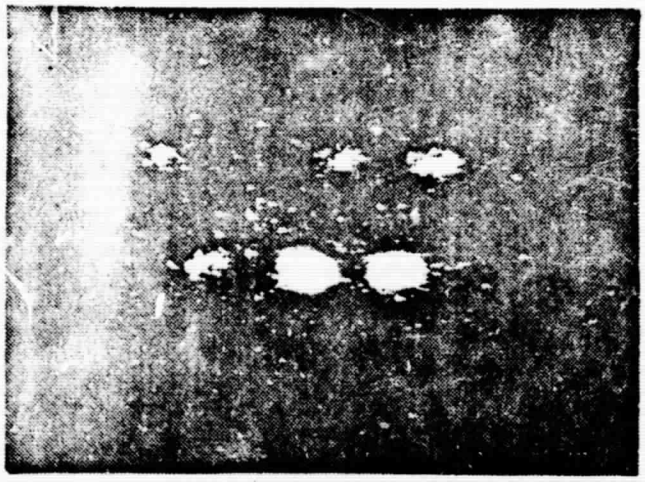
I-40



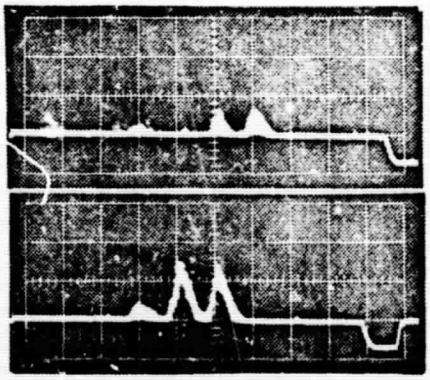
I-41



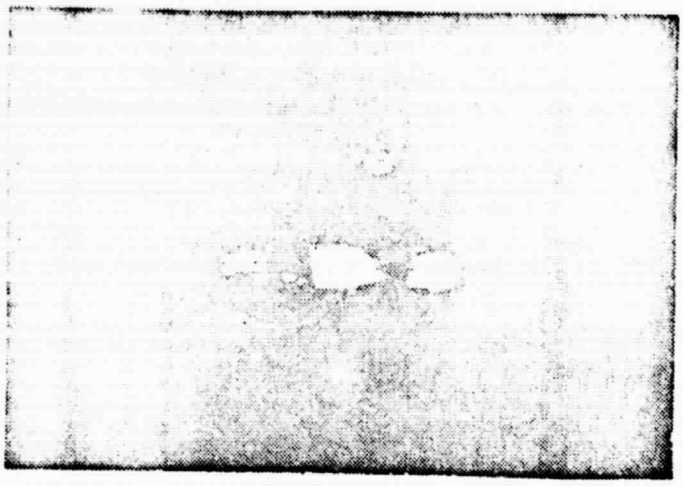
I-42



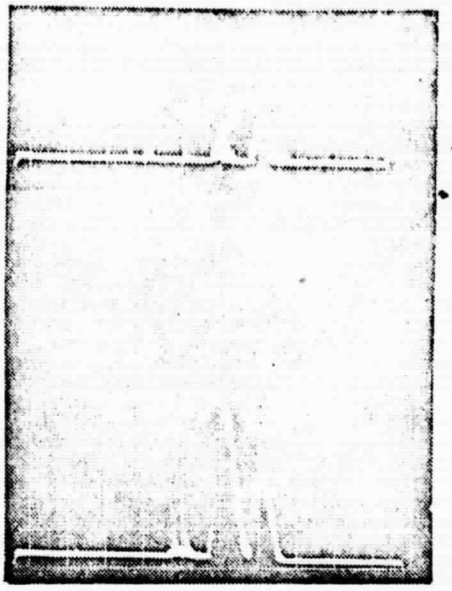
I-43



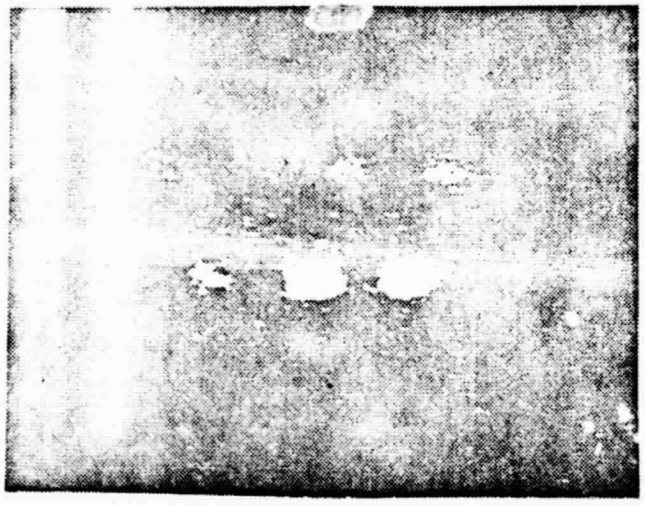
I-44



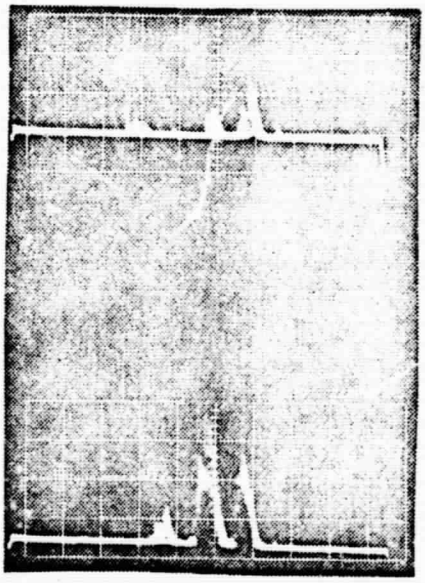
I-45



I-46



I-47



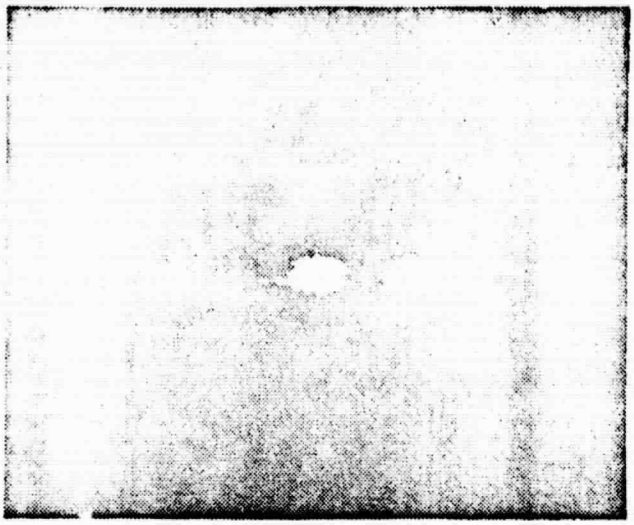
I-48

Figure I-49. Video monitor. Same as figure I-39 except that a ~~Corning~~ Kodak 15g has been installed on the receiver.

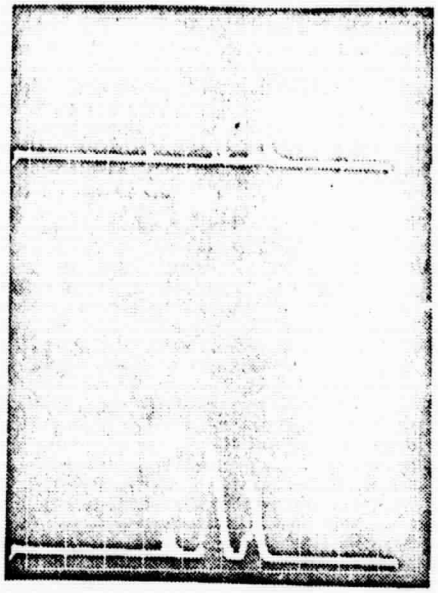
I-50. A-scope. Same as figure 49. 20 mv/cm.

I-51. Video monitor. Same as figure I-39 except that a ~~Corning~~ Kodak 16 has been installed on the receiver.

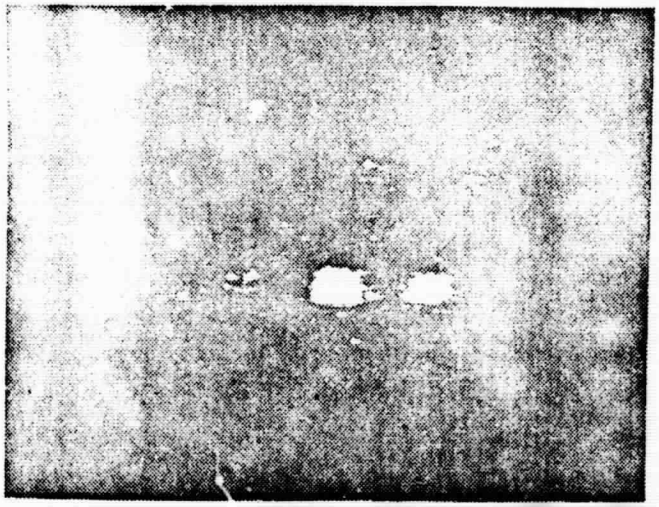
I-52. A-scope. Same as figure I-51. 20 mv/cm.



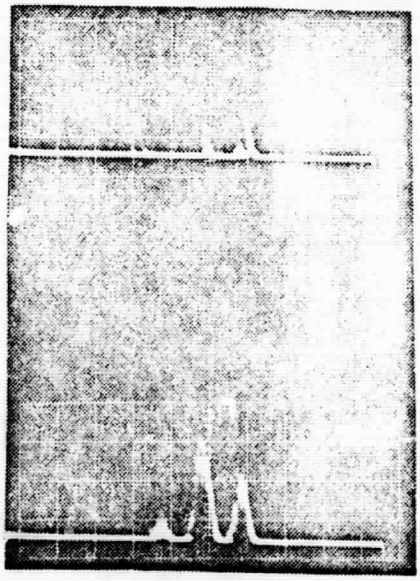
I-49



I-50



I-51



I-52

Figure I-53. Video monitor images of seven Group II specimens used in the study of transmitter power. Layout of specimens is shown in Appendix F. In the top row, left to right: magnesium oxide, willemite, fluorite, and calcite. In the bottom row, left to right: calcite veins in limestone, phosphate, and colemanite. Receiver is filtered with a Corning 3-73. Input power is .25 ma at 20,000 volts.

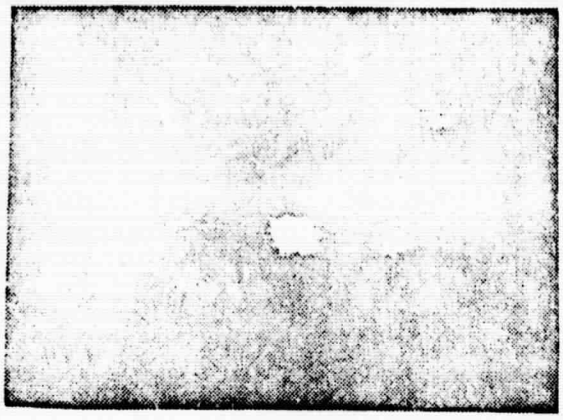
I-54. A-scope. Same as figure I-53. 20 mv/cm.

I-55. Video monitor. Same as figure I-53 except that input power is .5 ma at 20,000 volts.

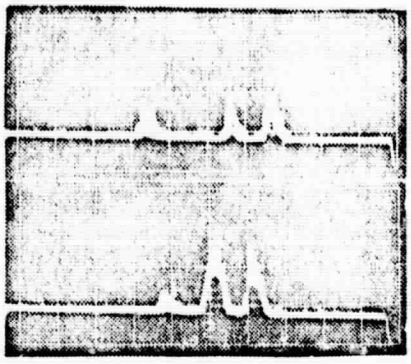
I-56. A-scope. Same as figure I-55. 20 mv/cm.

I-57. Video monitor. Same as figure I-53 except that input power is 1 ma at 20,000 volts.

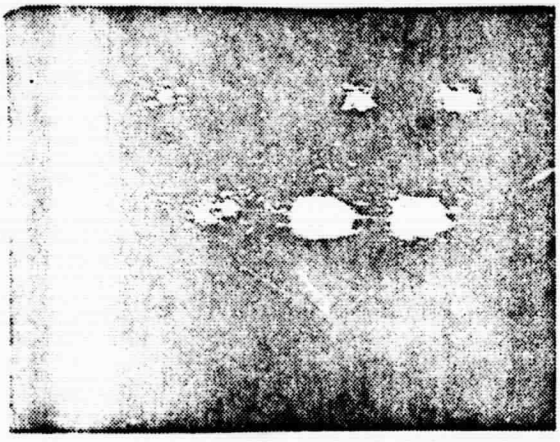
I-58. A-scope. Same as figure I-57. 20 mv/cm.



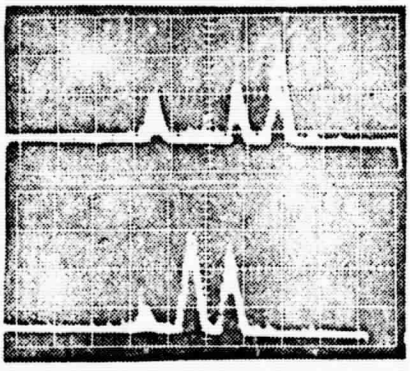
I-53



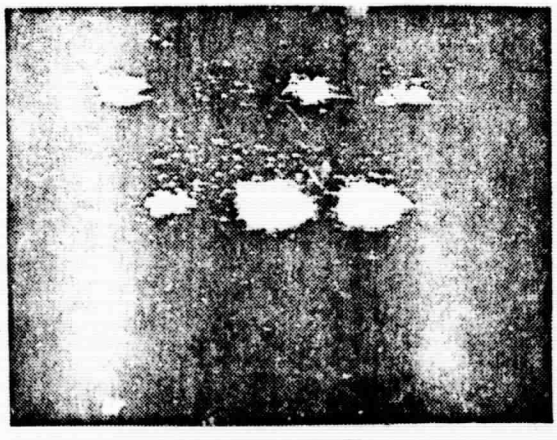
I-54



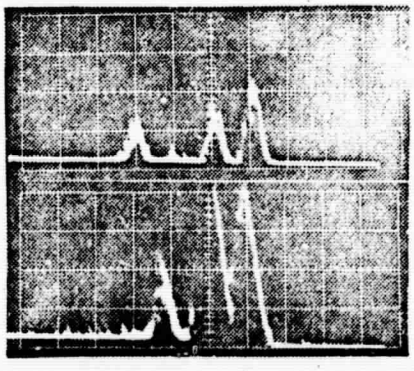
I-55



I-56



I-57



I-58

REFERENCES

Dake, H.C., 1941, Fluorescent light and its applications: Brooklyn, Chemical Publishing Company, Inc.

Gleason, Sterling, 1960, Ultraviolet guide to minerals: New York, D. van Nostrand Company.

Levshin, V.L., 1958, The study of luminescence phenomena and development of their applications in the Soviet Union, Uspekhi Fizicheskikh Nauk, v. 64, n. 1; trans. for the U.S. Atomic Energy Commission and the National Science Foundation, Washington, D.C., by the Israel Program for Scientific TRanslations, 1964.

Kroger, F.A., 1948, Some aspects of the luminescence of solids: New York, Elsevier Publishing Co.

Leverenz, H.W., 1950, An introduction to luminescence of solids: New York, John Wiley and Sons; London, Chapman and Hall.

Westinghouse Electric Corporation, 1963, Ultraviolet mapping optical radar system, unpublished report, negotiation no. AAN - 32263.

Ibid, 1962, Ultraviolet active imaging and ranging, unpublished report, negotiation no. AAN - 35426.